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IGR TRANSLITERATION OF RUSSIAN

The AGI Translation Office has adopted the essential features of Cyrillic transliteration recommended by the U. S Department of the Interior, Board on Geographic Names, Washington D. C.

Alphabet		transliteration
А	а	a
Б	б	b
В	в	v
Г	г	g
Д	д	d
Е	е	e, ye (1)
Ё	ё	ë, yë
Ж	ж	zh
З	з	z
И	и	i (2)
Й	й	y
К	к	k
Л	л	l
М	м	m
Н	н	n
О	о	o
П	п	p
Р	р	r
С	с	s
Т	т	t
У	у	u
Ф	ф	f
Х	х	kh
Ц	ц	ts
Ч	ч	ch
Ш	ш	sh
Щ	щ	shch
Ъ	ъ	" (3)
Ы	ы	y
Ь	ь	' (3)
Э	э	e
Ю	ю	yu
Я	я	ya

However, the AGI Translation Office recommends the following modifications:

1. Ye initially, after vowels, and after ъ, ь. Customary usage calls for "ie" in many names, e. g., SOVIET KIEV, DNIEPER, etc.; or "ye", e. g., BYELORUSSIA, where "e" follows consonants. "e" with dieresis in Russian should be given as "yo".
2. Omitted if preceding a "y", for example, Arkhangelsky (not "iy"; not "ii").
3. Generally omitted.

NOTE: Well-known place and personal names that have wide acceptance will be used. Some translations may include elements of previous German transliteration from the Russian; this occurs in IGR most commonly in maps and lists of references. The reader's attention is called to the following variations between German and English systems which may cause confusion when trying to check back to original Russian sources.

German	English
w	v
s	z
ch	kh
tz	ts
tsch	ch
sch	sh
schtsch	shch
ja	ya
ju	yu

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METHODS OF MERCUROMETRIC INVESTIGATIONS[1]

by

E. A. Sergeev

• *Translated by Ivan Mittin* •

ABSTRACT

A spectroscopic method of analysis of rocks for the presence of mercury in minute concentra-ion is described. Sensitivities to 0. 02 ppm are possible. Its usefulness in geochemical explora-ion is illustrated by application of the technique to the Khaidarkanskoe ore field. Variants of the method and examples of other successful field applications are given. -- M. Russell.

* * *

In a well-known monograph "Geochemistry of mercury" its author A. A. Saukov (1946) makes an interesting practical deduction: "The considerations expressed above can evidently be used as a basis for a mercurometric survey of districts and regions in the form of geochemical mapping and as a method of prospecting for mercury deposits."

This deduction was based on the concept that mercury is widely dispersed, its mean content in the earth's crust being 7×10^{-6} percent (70 ppb), but there is a differentiated distribution in diverse igneous and sedimentary rocks, such as persilicic and subsilicic igneous rocks, limestones, schists, etc. In addition, the content of mercury in the dispersion aureole of deposits was known to approach 10^{-4} to 10^{-3} percent (1 to 10 ppm). This all indicated the possibility of successful prospecting for deposits of mercury by its aureoles of dispersion.

This proposition by A A. Saukov, however, has not been properly developed, apparently because of difficulties in carrying out field work on the basis of the method worked out by him for a high-sensitive but laborious nephelometric analysis of samples for mercury.

From the point of view of the modern formulation of the question of primary aureoles of dispersion of ore deposits, two clauses of the article mentioned are of special interest.

In the first place, A. A. Saukov noted the high pressure of mercury vapor and of its compounds in hydrothermal solutions, and consequently, their power to penetrate deeply into country rock and to form vast aureoles of primary dispersion extending hundreds of meters beyond the ore body itself.

The second important suggestion is that mercury as a chalco-phylic element tends to accumulate in deposits of a sulfide type, as has been proven on specific material. A. A. Saukov showed that quantities of mercury in most minerals from sulfide-polymetallic deposits are higher than the clarke and the amount of mercury in these minerals increases from hypothermal to mesothermal deposits and attains the maximum in epithermal deposits. The content of mercury for 14 basic sulfide minerals (molybdenite, pyrrhotite, pyrite, sphalerite, galena, chalcopyrite, gray copper ores, bornite, bournonite, chalcocite, marcasite, antimonite, realgar, orpiment) was found to range from 1 to 100 ppm, varying with the kind of mineral and the region. Thus, for instance, gray copper ores of the Nikolaevskii deposit in the Altai region contain up to 4.2×10^{-3} percent (42 ppm) mercury, and some ores in the Caucasus up to 100 ppm.

The most recent investigations by Novokhatskii and Kalinin (1952) indicated that the majority of the sphalerite specimens analyzed by them contained quantities of mercury in the order of 10 ppm, reaching 150 ppm in minerals from low temperature deposits. According to their data, copper minerals were characterized by mercury content of up to 1, 500 ppm.

In summarizing the given facts and considerations and taking into account the ubiquitous presence of sulfide minerals in most hypogene deposits, one should assume that the quantity of mercury in the mineralized zones of most ore deposits is tenfold to more than a hundredfold times its clarke value and that the mercury introduced is much more widely distributed than has been thought previously. Insufficient knowledge of this problem is explained by the complexity of the analysis for small quantities of mercury by means of the existing methods.

To document the suggestions made above, one can refer to the observations by I. I. Ginsburg on the presence of aureoles of mercury around pyrite deposits of the South Urals. Also of interest is a reference by V. E. Poiarkov to the industrial recovery of mercury from the dust obtained during the treatment of tin ores

---

[1] Translated from Metodika rtutometricheskikh issledovanii: in Geokhimicheskiye poiski rudnykh mestorozhdenii v SSSR. [Geochemical prospecting for ore deposits in the U.S.S.R.], 1957, pp. 158-165. Translation edited by T. S. Lovering. Publication authorized by the Director, U. S. Geological Survey.

in Sardinia. According to A. A. Saukov, in connection with phenomena of sorption of mercury by highly dispersed systems, a considerable enrichment in Hg has been observed in manganese ores, up to n x 10^{-4} percent (n. ppm) and also in brown iron ore and other dispersed systems (including clays). He also proved possible isomorphism of mercury with barium and calcium, the content of mercury in barites of quicksilver districts and general ore districts ranging from 2 x 10^{-3} percent (20 ppm), to 1.9 x 10^{-2} percent (190 ppm) (Tiuia-Muiun) [Tyuya-Muyun], and in fluorites - up to 7 x 10^{-4} percent (7 ppm).

If we compare two geochemical features of the behavior of mercury in the lithosphere — namely: the high mobility of vapors and solutions of mercury and its compounds during processes of ore deposition which should result in the formation of strong hypogene dispersion aureoles on the one hand, and on the other, the regular connection of mercury with minerals of most ore deposits, which commonly contain mercury 2 or 3 orders of magnitude greater than the clarke, - we have good reason to utilize them for practical purposes. It seems advisable to consider on this basis the possibility of utilizing the aureoles of dispersion observed in both surface deposits and bedrock as indicators of hypogene ores and to some degree as a general indication of any ore deposit.

To study this possibility, methods of analysis for mercury in rocks must be rapid and of high quality. The sensitivity of these methods must be close to the clarke of mercury and at least 1 or 2 orders of magnitude greater than its anticipated content in the zones of mineralization. The sensitivity of analysis determined by values n x 10^{-6} or even n x 10^{-7} percent (10-100 ppb) satisfies these requirements. In 1954-1955 P. A. Stepanov and the author developed two variants of a rapid and highly sensitive method of spectrographic analysis of rocks for mercury.

As is known, the usual methods of the emission spectrographic analysis of rocks permit detection of mercury when its content in the material analyzed is not less than hundredths of one percent. Such a low sensitivity of the spectrographic analysis for mercury is a consequence of two circumstances connected with the conditions of excitation of the spectrum of metalometric samples.

The first circumstance is intensive evaporation and excitation of many elements of the sample, the ionization potentials of which are much lower than that of mercury. For the sake of comparison, the values of ionization potentials of common elements of the mineral substance of a metalometric sample are given below:

Ionization potentials for sodium, potassium, calcium, and magnesium are lower or equal to 6 electron-volts; for silicon, titanium, manganese, iron, and nickel do not exceed 8 electron volts, but for mercury the value is 10.6.

The substantial difference in values of the ionization energy and correspondingly, of the excitation of spectra, is an important factor. As is known, in a gas blend the spectra of the elements with a higher potential of excitation wane or even fade out entirely in the presence of vapors with low values of excitation energy.

The other reason for the inadequate sensitivity of analysis can be found in the high rate of evaporation of mercury that takes place in the common arc during the first few seconds of exposure. Under these conditions the fraction of mercury atoms that are excited may be very small.

Taking into account the foregoing discussion, in order to increase the sensitivity of analysis one can carry on certain processes separately e. g. the evaporation of mercury in a container having a small orifice and the excitation of its spectrum in vapors outside the container. This will permit providing the most favorable temperature conditions for both processes: a relatively low temperature for the evaporation of mercury in the closed volume and the much higher temperature required for the excitation of its characteristic spectrum from vapors outside the container.

Indeed, in order to achieve complete evaporation of mercury from compounds such as cinnabar and mercuric oxide, a temperature of not over 500-600° will suffice. At the same time under these conditions practically no evaporation of other metals will take place in the sample. At that time (in the apparatus devised) the plasm of the arc will contain, besides mercury, an atmosphere corresponding to a discharge between pure carbon electrodes with an effective ionization potential of about 12 electron-volts, very favorable for exciting the spectrum of mercury. At such temperature conditions, a gradual and more uniform inflow of vapors into the arc can be secured with a corresponding rise in the proportion of excited atoms.

In testing the scheme an excessive loss of mercury vapors through the walls of a cavity in the carbon electrode and in the fine grained carbon cap was noted; this lowered the sensitivity of analysis and its reproducibility.

As a result of investigations carried out, giving due consideration to the foregoing observations, a rapid technique of analysis

with a sufficiently high sensitivity was devised.[2]

The electrode carrying the material for analysis is of round steel of any grade, having an outside diameter of 11 mm. The cavity for the sample is 18 mm long and the diameter 5. 8 mm (the capacity of the electrode is about 0. 4 ml). The lower sealed part of the electrode has a projection for attaching it to a support (fig. 1).

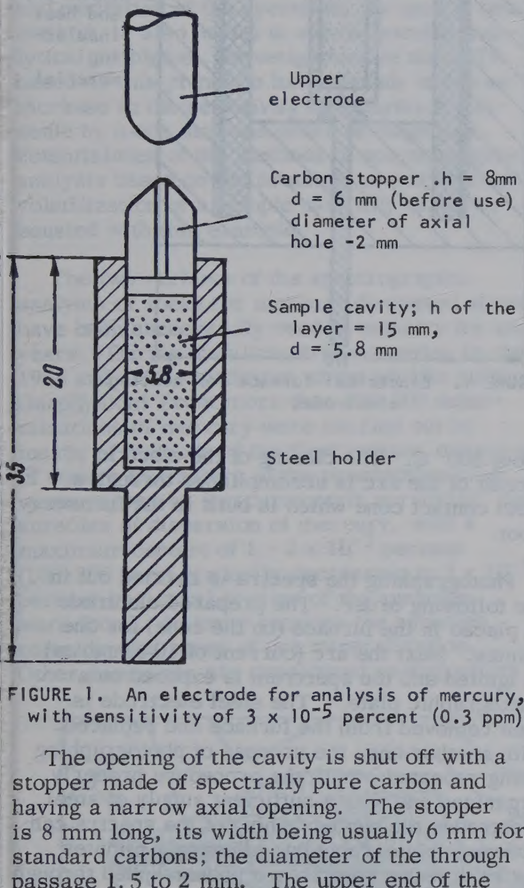

FIGURE 1. An electrode for analysis of mercury, with sensitivity of 3×10^{-5} percent (0.3 ppm)

The opening of the cavity is shut off with a stopper made of spectrally pure carbon and having a narrow axial opening. The stopper is 8 mm long, its width being usually 6 mm for standard carbons; the diameter of the through passage 1. 5 to 2 mm. The upper end of the stopper is pointed, i. e., cone-like.

The cavity of the steel electode is filled tightly with the powdered sample up to a level about 1. 5 to 2 mm from the brim. The sample placed in the steel electrode must be wetted with 1 or 2 drops of water to prevent its spouting during the arcing. Next the carbon stopper is tightly rubbed into the cavity to a depth of 1 to 1. 5 mm.

The electrode thus prepared is placed into the bottom holder of the arc stand. The arcing then occurs between the cone-like end of the carbon stopper and the ordinary upper electrode made of spectrally pure carbon. Arcs of either alternating or direct current can be used.

In filming the spectra, the current in the arc must be 10 amperes, the exposure time-60 seconds, and the width of the spectograph slit, 20 microns. Photographic materials and the process of developing are usual.

Steel electrodes are suitable for repeated use, no substantial changes in their qualities have been observed. The removal of the used specimen from the electrode offers no difficulties, as the powdered sample is only slightly calcined during the run but it does not bake and so remains friable.

Because of the high sensitivity of the method, traces of a previous sample with a high content of mercury can lead to contamination of the electrode. In such cases, cleaning can be best accomplished by means of one- or two-minute heating of a whole batch of electodes in an electrical oven at a temperature of 600°C.

During the photographic exposure of spectra a rotating stepped sector or a stepped platinum attenuator is used. The reading of spectrograms is carried beneath the spectro-projector, on the line 2536. 5 Å for concentrations from 0. 00003 to 0. 03 percent (6. 3 ppm to 300 ppm), and on lines 3131 Å; 2534 Å for concentrations of 0. 03 percent or over.

When photographing spectra of standard samples containing different amounts of mercury, a table is compiled to show the relation of the number of observed steps of the spectrum lines to the concentration in the standards.

The sensitivity of the method as described above is 3×10^{-5} percent which is sufficient for carrying out metallometric surveying in prospecting for deposits of mercury. A possible further appreciable increase of sensitivity at the expense of an increase in the volume of the batch for analysis was established and put into practice in a second variant of the method which then has a sensitivity for mercury of $1 - 2 \times 10^{-6}$ percent (0. 01 to 0. 02 ppm). In this variant, the electrode carrying the material for analysis has its capacity increased to 6 ml (as against 0. 4 ml in the first variant). The sketch in Figure 2 depicts an electrode represented by a steel cylinder, 70 mm high, with an inside diameter of 12 mm, and a wall thickness of 2 - 2. 5 mm; the upper part of the cavity in the steel cylinder is covered with a steel lid provided with an opening in the center into which a stopper of spectrally pure carbon with an axial canal is tightly inserted. The steel cylinder is tightly filled with crushed sample to a level 2 to 3 mm below the lid brim.

[2] The same principle was applied at the same time in the method proposed by A. K. Rusanov and M. M. Kler for the spectographic analysis of ores for mercury.

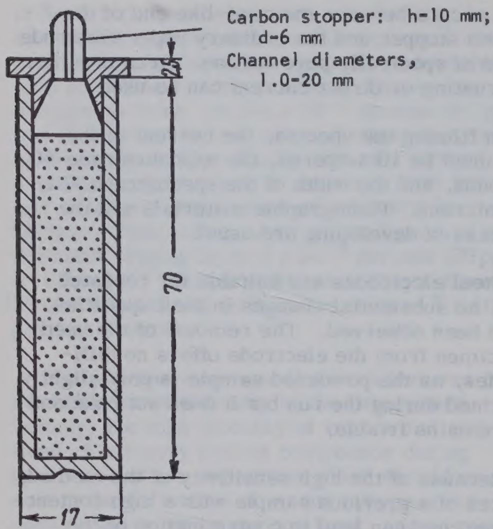

FIGURE 2. An electrode of 2 x 10^{-6} percent (0.020 ppm) sensitivity for determination of mercury

The excitation of the spectrum of mercury vapors is accomplished here also in an arc discharge between the carbon stopper and the upper carbon electrode. However, as the amount of heat from the arc discharge is not sufficient for initial heating of the sample to 500-600° in a short time, a small electrical furnace of the ordinary type (series ISP-22) is attached to the arc stand. This stand is shown on the drawing of Figure 3.

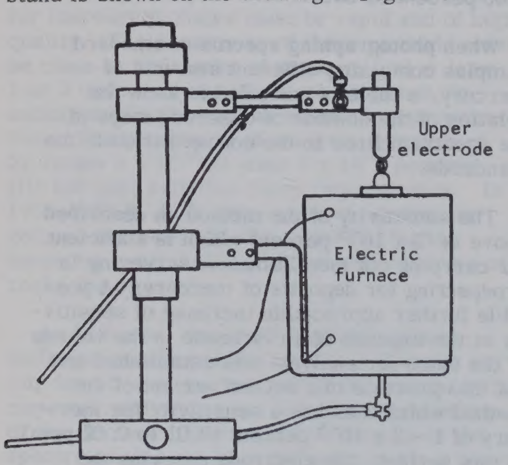

FIGURE 3. Device for analysis of mercury with a sensitivity of 2 x 10^{-6} percent

A separate sketch of this furnace is given in Figure 4. Omitting the details of its construction, we need only to point out that this furnace with a nichrome winding has a capacity up to 500-600 v[3] and a working temperature of

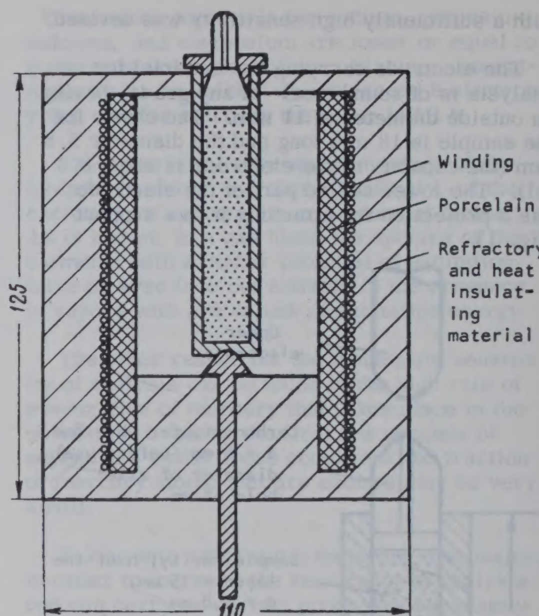

FIGURE 4. Electrical furnace for heating electrodes

about 800° C. The closing of the electric circuit of the arc is accomplished through a steel contact cone which is built in the furnace floor.

Photographing the spectra is carried out in the following order. The prepared electrode is placed in the furnace (on the cone) for one minute. Next the arc (current of 10 amperes) is ignited and the spectrum is exposed on a photographic plate. The steel electrode is then removed from the furnace and replaced with another one, the process of photographing being repeated. With the procedure properly organized and with a sufficient supply of steel electrodes the photographing of the spectra can proceed uninterruptedly, allowing 4 minutes for each test. Spectra are photographed through a stepped sector or a platinum attenuator. The quantitative interpretation of the spectra is accomplished in the manner similar to those described earlier. The concentrations to be determined lie within a range from a fraction 1 - 2 x 10^{-6} percent (0.01 - .02 ppm) to the integral percent units with only three lines used: 2536 Å, 3131 Å, 2534 Å. In both variants of the method the sample is crushed to about 100 mesh size.

It should be noted that in developing the method we have not sufficiently studied the effect of the physicochemical condition of mercury in the test on the analysis. On the basis on general considerations and experimental data by S. K. Kalinin (Novokhatskii and Kalinin, 1952), some difference can be expected in estimating the concentration depending on whether the mercury is found as an

[3]"v" in original text, but may be an error; probably "ohms" is intended.--T.S.L.

isomorphous admixture in other minerals or in its own mineral compound.

The reproduction of results by means of the described analysis procedures corresponds to the usual level of the semiquantitative spectrographic analysis of metallometric tests.

It is interesting to note that the principle of carrying separate processes of volatilization and excitation of the spectrum, as used in this method, is also useful in solving similar analytical problems. Investigations of the VITR based on this principle have already led to an increase in the sensitivity of analysis for arsenic by more than one order of magnitude. Potentialities of the methods of spectrographic analysis based on the principle of a fractional volatilization of a sample naturally is not exhausted with this example.

The two variants of the spectrographic analysis of rocks for mercury discussed above have been successfully used in industry for two years. During metallometric surveying by the 1954 and 1955 expeditions of the Middle Asiatic Geophysical Trust more than 100, 000 determinations of mercury were carried out by means of methods of the first variant. Hundreds of square kilometers of the prospective area were mapped by mercurometric surveying, and aureoles of dispersion of mercury, with a maximum content of 1 - 2 x 10^{-2} percent (100-200 ppm) gradually decreasing to 3 x 10^{-5} percent (0. 3 ppm) at rims of the aureoles, were found. In many sections the aureoles coincide with zones of ore mineralization. Other anomalies are considered as suggestive of new ore areas. An example of this type of work, a map showing results of the mercurometric survey, is given in Figure 5.

In 1955 a mercurometric survey on a scale of 1:10, 000 mapped a number of strips of the Khaidarkanskoe ore field. Aureoles of a mercury concentration in sediments to 3 x 10^{-3} percent (30 ppm) were ascertained above the block of commercial ores discovered by the exploration. At the same time aureoles of dispersion just as rich and more sustained were discovered in the adjacent sections not reached by the mine working. Thus, considering the rapidity of the methods of the spectrographic analysis, mercurometric explorations should be regarded as qualified for wide application in geologic-prospecting practice.

The second variant of the spectrographic analysis for mercury (with large electrodes) was employed in 1956 in determining mercury aureoles in sections of the polymetallic mineralization. The VITR investigations in sections of one of lead deposits established a content of mercury in the friable (mantle) and bedrocks of the sedimentary complex near the ore body. Mercury concentrations here were very low, frequently beyond the range of the analysis sensitivity (1 - 2 x 10^{-6} percent). However, regular increases of concentration to 7 x 10^{-5} percent (0. 7 ppm) coincided areally with the explored block of commercial lead ores as shown in Figure 6.

A. P. Solovov, using the same methods, ascertained the presence of mercury with a maximum of 6 x 10^{-4} percent (6 ppm) in the

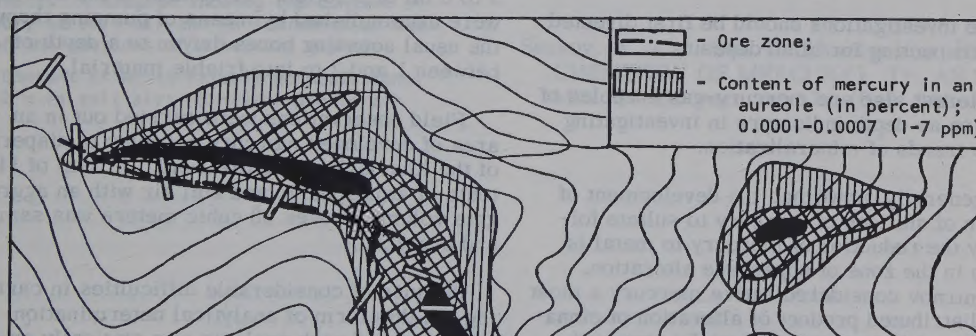

FIGURE 5. A map of mercurometric surveying

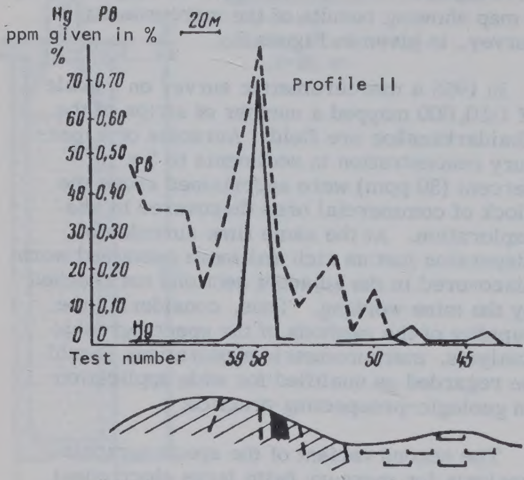

FIGURE 6. A diagram showing contents of mercury and lead in friable accumulations of one of the deposits

- Ore   Country rock

aureole of the ore body at a depth of 25 m from the surface in the Achisaiskii polymetallic deposits.

The facts given signify that successful application of mercurometric investigations is possible in prospecting for sulfide polymetallic deposits; they represent an adequate basis for arranging wide systematic investigations in this direction in various metalogenetic regions of our country, utilizing the described methods of rapid spectrographic analysis of samples for mercury.

These investigations should be first directed to the prospecting for blind deposits.

Of interest also are mercury-gas aureoles of dispersion as depth indicators in investigating possible trends of mineralization.

It is generally known that the development of oxidation of sulfides of mercury to sulfate followed by the reduction of mercury to metal is possible in the zone of supergene alteration. S. S. Smirnov considered native mercury a most widely distributed product of alteration of cinnabar in the oxidation zone, though he stressed limitations of the development of this process. On the other hand, in examining processes of the primary ore formation, A. A. Saukov writes: "Inasmuch as the diluting (of sulfide solutions - ES) is apparently one of the most important factors in the precipitation of sulfide of mercury and it is associated with the simultaneous precipitation of metallic mercury, --it is perhaps one of the ways of formation of native mercury in nature".

In the light of these concepts native mercury can be accepted as a necessary associate (or a product) of the hypogene mercuric mineralization and also of surface oxidation processes of primary ores. The latter provides a basis for assuming in sections containing large amounts of mercury in different forms the existence of mercury-gas aureoles of dispersion having a relatively high concentration of mercury vapors in pores and cavities of country rocks and also in the subsurface air.[4]

To confirm the existence of this kind of aureoles of dispersion, investigations were conducted in the VITR laboratory of geochemical methods by employing the technique for determination of mercury vapors in air, prepared by L. S. Margolin and designed for the minimum concentration of the earth's mercuric atmosphere (<0.02 v/m^3 where v = 10^{-9} gm).

The absorption of mercury from air was accomplished by reacting the iodine in a solution of potassium iodide with vapors of bromine drawn through it — to maintain an actively absorbing solution during the entire and rather long operation of passing air through the absorbent. Mercury was determined by means of the known Polezhaev reaction. Variations of conditions of this reaction permit increasing sharply its concentration sensitivity (the maximum dilution 2.5 x 10^8 instead of 1 x10^7 of the published data).

The approximate quantitative evaluation of the content of mercury in samples, starting from 0.01 microgram, was carried out by comparing the stained sediments with the standard scale prepared in a similar way. The scale used was: 0 - 0.02 - 0.05 - 0.1 micrograms of mercury for 5 to 8 ml of solution. Samplings of the soil air were accomplished by means of pumping through the usual sounding bores driven to a depth of between 1 and 2 m into friable material.

Field observations were carried out in an area of developed mercury aureoles of dispersion of the Khaidarkanskoe ore field. A total of 110 tests of atmospheric and soil air with an aggregate volume of over 33 cubic meters was sampled and analyzed.

Because of considerable difficulties in carrying out this form of analytical determination, the course of each analysis was critically examined for possible errors caused principally by the contamination of the absorbing concentrate. As a result, only one-third of the operations completed were accepted as sufficiently reliable for further study. Moreover, each

[4]Many researchers regard the evaporation of sulfide of mercury as possible at ordinary temperatures and pressures. Therefore, the composition of mercury-gas aureoles could be assumed to contain also vapors of mercury sulfide.--Auth.

item of this series corresponding to a definite sample site was characterized on the basis of two, three, or four-time core samplings and their analysis.

A study of the data obtained establishes the following facts: All the tests of the atmospheric air in the profile section under investigation indicated a mercury content of the order of 0.01 micrograms, but at any rate not over 0.02 micrograms per cubic meter. Tests of soil air, in contrast to these low values, indicated a relatively high content of mercury, attaining decimal fractions of a microgram per cubic meter.

A diagram showing the content of mercury vapors in ground air in the profile section in contrast with the change of the solid aureole in the same section is given in Figure 7. Deserving attention is the conformity in the course of curves for aureoles in solid and gaseous phases.

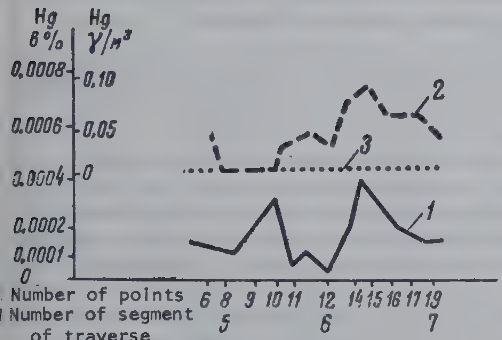

FIGURE 7. A diagram showing the content of mercury in soil air and in sediments of one of the sections of a mercury deposit.

1 - Content of Hg in friable accumulations; 2 - in soil air; 3 - atmospheric air

In other sections in which the results of analyses as established by checking were definitely excessive, the above mentioned conformity in the content of mercury in (solid phase?) accumulations and in soil air was not observed.

We appraise the material presented above as a preliminary experiment not pretending to establish any relationships, except to sufficiently substantiate the assertion that high concentrations of mercury vapors exist in the soil air in the area of development of the solid phase mercuric aureole.

This provides a basis for regarding a subsequent study of modern mercury-gas aureoles as a problem of real interest, though its practical significance is not clear yet.

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AUTOMETASOMATIC ALTERATION OF GRANITOIDS AND ASSOCIATION OF TIN MINERALIZATION WITH THE ZONE OF SODIUM-POTASSIUM METASOMATISM[1]

by

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ABSTRACT

Different forms of high-temperature alkaline autometasomatism in granitoids of certain tin-bearing massifs in the upper course basin of the Kolyma River are considered. The relative depths of massif development have been established from the degree of erosional shearing, higher in massifs enclosed in anticlinal structures.

In massifs developed at the greatest depth the reciprocal replacement of feldspars is accompanied by the destruction of the crystalline lattice of the replaced mineral. In plagioclase formed in place of K-Na-feldspar, myrmekite intergrowths are common; their amount and even their appearance itself depend chiefly on the degree of difference between the crystalline lattice orientation of the replaced and replacing feldspars.

As the depth of massif development in granitoids decreases, metasomatic replacement with preservation of the replaced feldspar crystalline lattice becomes more frequent in massifs of the least depth of development; such a kind of alkaline autometasomatism is most widespread.

In granitoid massifs of all depths, the formation of metasomatic K-Na-feldspar occurs before the development of metasomatic acid plagioclase varieties. From this it becomes possible to establish two stages of alkaline autometasomatism: an earlier potassium and later sodium stage.

In chessboard plagioclases twins develop according to the (010) law with a rhombic section as twinning seam; they intergrow also along the (010)-plane, the perpendicular raised to the latter almost coinciding with (010) and making the impression of albite twinning. Besides in chessboard albites the (001)-law is common (twinning seam (010) with an additional intergrowth along the rhombic section; the perpendicular raised to the latter showing several degrees of deviation from (001)).

All of the tin showings associated with the massifs under consideration spatially coincide with the rock zone where the feldspar replacement takes place with the crystalline lattices preserved. Therefore, in massifs of the greatest depths of development the tin showings are located at the exocontacts; and as the depth of development decreases they move towards the central parts of the massifs. --Author's English Summary.

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INTRODUCTION

The high-temperature autometasomatic alteration of intrusive rocks, mainly granitoids, attracts the attention of geologists more and more. Such phenomena of alkaline metasomatism as microclinization and formation of acid plagioclases are frequently described in the literature. However, in most cases these descriptions are not accompanied by data on detailed investigations of the properties of newly formed or primary minerals, or by materials referring to the study of forms of replacement of one kind of minerals by the others. This does not allow us to judge physicochemical conditions of the autometasomatic process.

It is possible to establish the regularity in consecutive manifestation of different kinds of metasomatism in time and space by studying the character of autometasomatism depending on changes of geological conditions in the formation of intrusive bodies.

The interpretation of property changes in rock-forming minerals – feldspars in particular – depending on the alteration in geological conditions of massif formation permits us to solve more satisfactorily the separate parts of the granite problem. However, this is impossible to do (Tuttle and Keith, 1954) if only field geology is applied, data of which are interpreted by different investigators in different ways.

Attempts to establish the origin of separate granite bodies, taking into consideration phenomena of postmagmatic recrystallization of rocks and explaining these phenomena by findings in

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[1] Translated from Avtometasomaticheskoe Izmenenie Granitoidov; Priurochennost Proyovleniy Olovonosnosti k Zone Natrovo-Kalievogo Metasomatoza: Sovetskaya Geologiya, v. 2, no. 8, Aug. 1959, pp. 61-80.

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the experimental study of rock-forming minerals, are reflected in the literature. O. F. Tuttle and M. L. Keith (1954), comparing the properties of minerals of young rhyolites and those of ancient granites, and having established that the properties of minerals of the first and second rocks are close, concluded that the Tertiary granites are of primary-magmatic origin.

It appears that by comparing all properties of rocks (including the properties of minerals) of massifs which formed at different depths, it is also possible to draw conclusions on the origin of the granites being compared, because these properties must be largely the result of the latest process of autometasomatism. In general, the character of autometasomatic alteration of granitoids will depend on depth of formation of the massifs. In other words, the regularities deduced by D. S. Korzhinsky (1953a) for metasomatism with the gradient of temperature and pressure must be justified for the process of autometasomatism.

My data shows that many properties of rocks and minerals are changing regularly, depending on the depth of formation of the granitoid massifs. All together, these alterations can best be explained considering phenomena of post-magmatic recrystallization. Depending on the depth of formation of massifs, there are changes in a) the form of metasomatic replacement of one group of minerals by others; b) the mineral and chemical composition of granitoids; c) the amount of perthite intergrowths in potash-soda feldspars; d) basicity of plagioclase; e) crystallo-optical properties of potash-soda feldspars; f) the amount of trace elements in rocks and monomineral fractions, and g) the amount and qualitative features of some accessory minerals. Besides, some regularities have been noticed in the change of character and position in space of tin mineralization depending on the autometasomatic alteration of granitoids.

This article will consider forms of replacement of earlier granitoid feldspars by later feldspars in the process of autometasomatism, depending on the depth of formation of massifs, and the related changes of character and location of tin mineralization.

MASSIFS STUDIED AND THE BASIS FOR DETERMINATION OF RELATIVE DEPTH OF FORMATION

The following granitoid massifs were studied: Verkhne-Omchansky (or Pravo-Seymkansky), Urchano-Buralkitsky, Olchano-Anmanmandzhinsky, Tenkeliysky, small outcrops, and Gerkules.

As may be seen from Table 1, the rock composition of these massifs differs. The leucocratic granites of the Verkhne-Omchansky massif are the most acidic, while the most basic are the granodiorites of the Gerkules massif.

The granite massifs considered are on the right bank of the middle and upper course of the Detrin River, one of the upper right tributaries of the Kolyma River, in the immediate vicinity of the Ust'-Omchug village, the center of administration of Tenkinsky district in the Magadan region.

All these massifs are located within one geotectonic province, designated in 1956 by Kh. I. Kalugin as the Detrino-Adychansky synclinorium. According to V. V. Belousov, this synclinorium is characterized by intermediate folding.

The interrelations of the Verkhne-Omchansky and to some extent of Olchano-Anmanmandzhinsky massifs with the effusives, and interrelations of the rest of the massifs with dikes which represent the roots of these effusives, indicate that the massifs were formed during the period between eruptions producing the porphyry effusives and those producing the acid (mottled) tuffs. The Upper Cretaceous age of these series is determined by analogy with rocks from adjacent regions bearing fossil plants. The age of Urchano-Buralkitsky and Tenkeliysky massifs is less definite. These massifs are considered to be Upper Cretaceous, but they are possibly younger.

Tin is genetically associated with rocks of

TABLE 1

Massif	Average Content (I), Maximum (II), and Minimum (III)														Number of calculations
	Plagioclase			Potash feldspar			Quartz			Biotite and Amphibole			Accessory Minerals		
	I	II	III	I	II	III	I	II	III	I	II	III	II	III	
Verkhne-Omchansky	20	26	2	41	58	25	35	40	29	3	6	0.5	2	0.1	120
Urchano-Buralkitsky	27	47	13	35	48	22	33	42	20	4	8	1	1	0.2	14
Olchano-Anmanmandzhinsky	24	34	17	42	46	38	29	34	18	5	7	4	1.2	0.2	17
Tenkeliysky	32	57	16	33	54	12	29	43	17	5	14	1	0.4	0.1	37
Small Outcrops	33	50	17	31	48	18	28	49	17	7	13	3	0.9	0.1	5
Gerkules	48	63	28	14	30	3	24	40	16	14	20	10	0.9	0.1	80

the Verkhne-Omchansky, Urchano-Buralkitsky, Tenkeliysky and Gerkules massifs. Tin associated with granitoids of Olchano-Anmanmandzhinsky massif is insignificant.

All massifs are emplaced in shales of like composition but different age (ranging from Karnian and Jurassic, as in the case of Verkhne-Omchansky massif, to Permian, as in the case of Gerkules massif). The Verkne-Omchansky massif has in places intrusive contacts with the effusives of the Upper Cretaceous porphyry series.

Conclusions concerning the relative depth of formation of granite massifs are based on the views of V. V. Belousov (1954) about the duration of formation of interrupted and intermediate folds.[3] The latter are highly developed in the southwestern part of the Okhotsk-Kolyma watershed. Here it has been frequently and clearly established that the vertical movements of the crust which formed these folds maintained their direction after the formation of intrusive bodies. Therefore, the rocks ranging in age from Permian to Upper Cretaceous are folded according to the same pattern. This explains the formation of horsts and grabens where the corresponding anticline and syncline folds were formed earlier. Finally, for the same reason, the middle massifs of the same age, or parts of the massifs located in the central portions of anticlinal folds, were uplifted and consequently eroded deeper than were the massifs or parts of massifs on the wings of the same folds, and much more than in adjacent synclines.

Such a relation of depth of formation of massifs to their tectonic position is complicated by the position of the region itself in that part of the Detrin-Adychansky synclinorium, where it is influenced by dipping of the hinge of the adjacent Khenike-Detrin anticlinorium. This last circumstance caused the greatest uplift and resultant maximum erosion of the massifs and the enclosing rocks located near the Khenike-Detrin anticlinorium, and the least uplift in the Verkhne-Omchansky massif, which is the most remote from this anticlinorium.

These features of geological structure in the region under examination determined the distribution of massifs according to their formation depth in the order reflected by the list at the beginning of this paper. The Verkhne-Omchansky massif formed at the least depth, and the Gerkules massif at the greatest.

[3] The intermediate folds are characterized by lack of similarity between synclines and anticlines. --E. A. A.

FORMS OF ALKALINE AUTOMETASOMATISM

During different periods of postmagmatic process, hydrothermal (or gaseous) solutions, flowing through pores and along fractures in rocks, from deep-seated parts of massifs to the peripheral parts, interact with the rocks and metasomatically alter them. Clear indications of such alteration are observed in thin sections of granitoids practically everywhere. Therefore, the study of autometasomatism in intrusive rocks, and particularly in granitoid rocks, is easier than study of the magmatic stage of formation of intrusive bodies.

It should be stressed again that in this paper, autometasomatic alteration of granitoids means an alteration connected with the highest-temperature postmagmatic solutions, corresponding to solutions of the early alkaline stage outlined in 1955 by D. S. Korzhinsky. The morphologic expression of such alteration is represented by:

a) Replacement of plagioclase (and other minerals) by potash-soda feldspar under conditions of strongly different orientation of their crystalline lattices.

b) Replacement of plagioclase by potash-soda feldspar under condtions of identical or very close orientation of the crystalline lattices.

c) Replacement of potash-soda feldspar by acid plagioclase under conditions of strongly differing orientation of the crystalline lattices.

d) Replacement of potash-soda feldspar by acid plagioclase under conditions of identical or very close orientation of their crystalline lattices, including the formation of replacement perthites.

These types of metasomatic replacement of one suite of minerals by another in the granitoid rocks under consideration, depend on postmagmatic solutions associated with the massifs being examined but not with some younger magmatic rocks. Replacement occurred within the solidified rocks. The former statement is supported by cases observed by the author of replacement of potash-soda feldspar by albite, and less frequently the replacement of plagioclase by potash-soda feldspar in young effusives and in intrusive dacites. It is necessary to stress that there are no young intrusive rocks in the vicinity of most of the massifs. The latter statement is supported usually by metasomatic alteration of major xenoliths found in ancient diorite rocks of the Verkhne-Omchansky massif. The same diorite rocks are part of the Olchano-Anmanmanzhinsky massif, and are located within the exocontact zone of the Gerkules massif. It is characteristic that forms of metasomatic replacement of primary plagioclases in diorites

by newly formed potash-soda feldspars are the same as autometasomatic interrelations of these minerals in granitoids of the corresponding massifs.

Showings of alkaline metasomatism were best seen from study of the mineral composition of rocks from the massifs under consideration. It has been established that, regardless of the type of replacement, the potash-soda feldspar always forms prior to the acid plagioclase. This may be explained by a sharp change in the composition of solutions with time. This conforms with S. S. Smirnov's opinion (1955) expressed in "The Problem of Different Composition of the Consecutive Portions of Distillates". It is therefore more convenient to describe autometasomatic alteration of granitoids according to stages (those of predominantly potassium and predominantly sodium metasomatism).

Stage of Predominantly Potassium Autometasomatism

Replacement of Primary Plagioclase by Potash-Soda Feldspar under Conditions of Arbitrarily Mutual Orientation of their Crystalline Lattices

In massifs formed at the greatest depths, potash-soda feldspar replaces plagioclase (and other early minerals) under conditions of arbitrarily mutual orientation of the replacing minerals and the minerals being replaced. Metasomatic formation of potash-soda feldspar is observed most clearly among the darker minerals. In areas occupied by the grains of potash feldspar which replaced biotite or hornblende (fig. 1) there are numerous inclusions

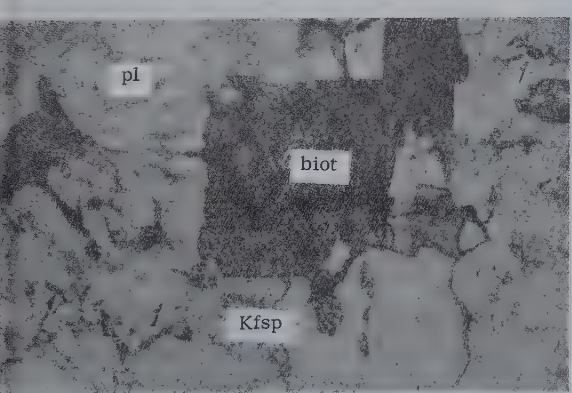

FIGURE 1. Hornblende-biotite granodiorite. Gerkules massif. Accumulation of accessory minerals (1) in potash-soda feldspar (kfsp) which replaced biotite (biot). X 34, thin section 109a.

of accessory minerals, mainly apatite, less frequently zircon, sphene and others. A certain part of these accessory minerals was formerly included in crystals of biotite and hornblende. However, an unusually high number of accessory minerals in potash-soda feldspar, as compared with their number in replaced dark-colored minerals, leads to the assumption that during the destruction of minerals being replaced, some elements – trace elements with the lowest tendency to migrate (phosphorus, titanium, evidently zirconium) – are not carried away by the solutions, but remain in place and form accessory minerals.

Inclusions of irregularly distrubuted relict grains of plagioclase, biotite, hornblende, and sometimes quartz, are usually observed in potash-soda feldspar. Under these conditions areas are formed with a monzonite structure of metasomatic origin, or the original monzonitic structure of the rock becomes more prominent. It is quite possible that microclinization in granodiorite intrusions of the Western Caucasus (G. D. Afanasyev, 1949) and in granitoids of Taymyr (O. S. Grum-Grzhimaylo, 1956) are analogous according to the type of replacement of earlier minerals by microcline during metasomatism of the nature described.

The replacement of plagioclase and other minerals by potash-soda feldspar has been observed in rocks of the Gerkules massif, and less frequently in the northern part of Tenkeliysky massif, indicating that these massifs formed at considerable depth, as indicated by the high-temperature autometasomatic alteration of the granitoids.

The variety of metasomatic alteration of the granitoids indicates the introduction of potassium and the removal of sodium, calcium, iron, and probably silicon. Autometasomatism of such type can be called potassium metasomatism in its proper sense, while massifs, or their parts, formed at the greatest depth and characterized by such alteration of the primary magmatic rocks, may be referred to the zone of potassium metasomatism proper.

Replacement of Primary Plagioclase by Potash-Soda Feldspar under Conditions of their Identical Orientation

Metasomatic replacement of plagioclase by potash-soda feldspar under conditions of their identical or very close orientation (figs. 2, 3) develops in granitoids of massifs at formed at lesser depths. In rocks of the Gerkules massif such replacement practically does not occur. In the Tenkeliysky massif this second type of metasomatic replacement of plagioclase by potash-soda feldspar is widespread, and in places within the endocontact areas predominates over the first. In rocks of the Olchano-Anmanmandzhinsky, Urchano-Buralkitsky, and Verkhne-Omchansky massifs this type of metasomatic replacement of plagioclase is developed exclusively. In the rock of massifs which formed at lesser depths

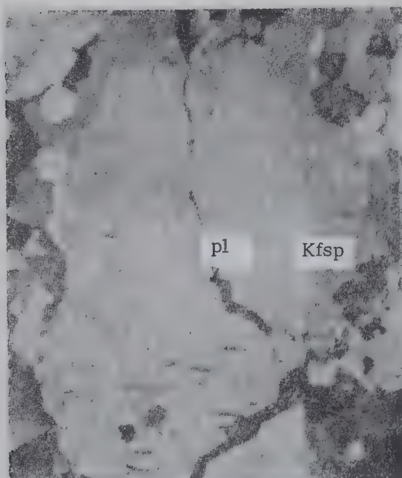

FIGURE 2. Porphyritic biotite granite, Verkhne-Omchansky massif. Border of metasomatic potash-soda feldspar (Kfsp) around the grain of plagioclases (pl). X15. Thin section 248-4.

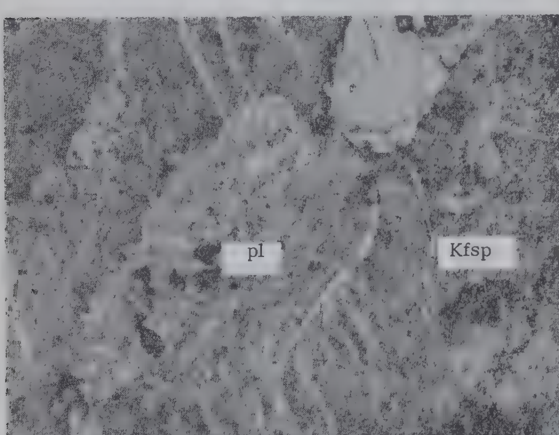

FIGURE 3. Medium-grained leucocratic biotite granite, Verkhne-Omchansky massif. Replacement of plagioclase (pl) by potash-soda feldspar (Kfsp) when both minerals are closely oriented. X70. Thin section 95.

such a process frequently results in complete replacement of the plagioclase grains, or plagioclase is present in the form of relicts in crystals of metasomatic potash-soda feldspar. Eleven measurements performed by means of the universal (Fedorov) stage on plagioclases being replaced and on replacing potash-soda feldspars permit us to make the following conclusions:

1) The identical indicatrix axes of both feldspars are located at a small angle to each other, and these two minerals have an almost simultaneous extinction. The identical cleavage planes of both feldspars usually coincide. In other words, their crystal lattices are located identically. Consequently, the replacement of plagioclase by potash-soda feldspar proceeds by substitution of potassium in the crystal lattice of plagioclase for sodium (and calcium).

2) The composition of the plagioclase being replaced varies from pure albite to oligoclase (no. 20-25). Evidently a partial albitization of plagioclase occurs immediately before the replacement, since the basicity of plagioclases in rocks of the Tenkeliysky massif and in small outcrops frequently reaches Ab. 60-55.

The alteration of rocks described develops with the introduction of potassium and sodium (preliminary albitization of plagioclase), and with the removal of calcium and sodium, as well as magnesium and iron, and partial replacement of dark-colored minerals by potash-soda feldspar. Such alteration of rocks may be called potassium-sodium autometasomatism, and massifs which are characterized by such alteration of primary magmatic rocks can be referred to the zone of sodium-potassium metasomatism. This zone is located hypsometrically higher than the zone of potassium metasomatism. From this we conclude that the zone of sodium-potassium autometasomatic alteration belongs to the lower-temperature type.

Conditions of Formation of Metasomatic Albite During the Stage of Predominantly Potassium Metasomatism

In massifs formed at very shallow depths potash feldspar is partially replaced by albite, which acquires the crystallographic orientation of the mineral being replaced. The transition from the zone of metasomatic development of potash-soda feldspar to the zone of albite formation occurs along a vertical distance of 20-40 m. This may be observed in Verkhne-Omchansky massif where the highest elevation on the watersheds consist of quartz-albite rocks with several varieties of albite. Albite is formed due to the removal of sodium from the higher parts of the massif. It is difficult to determine the amount of albite formed during this stage, because new albite does not differ from albite formed during the later stage of predominantly sodium autometasomatism. For this reason the replacement peculiarities of potash-soda feldspar by albite, and forms of this replacement, will be more conveniently examined later, when describing granitoid alteration during the stage of predominantly sodium metasomatism.

With the introduction of sodium during the process of similar alteration of granitoids, potassium, calcium, and to some extent iron and magnesium, are removed. Therefore, autometasomatism of this kind can be called soda autometasomatism, and parts of massifs formed at the shallowest depths may be referred to the zone of sodium autometasomatism. This zone is located hypsometrically higher than the

first two, and the character of the autometasomatic alteration is of lower temperature.

Stage of Predominantly Sodium Autometasomatism

Replacement of Potash-Soda Feldspar by Acid Plagioclase under Conditions of Different Crystallographic Orientation of Minerals; the Formation of Myrmekites

In granitoids formed at the greatest depths, many plagioclase grains have rims of acid-reaction plagioclase with myrmekitic intergrowths at the joints with grains of potash-soda feldspar. Most rims with myrmekitic intergrowths were found in rocks of the Gerkules massif, some in rocks of the Tenkeliysky massif, and a few in rocks of the Olchano-Anmanmandzhinsky massif. None occur in granites of the Urchano-Buralkitsky and Verkhne-Omchansky massifs. Thus, a decrease in depth of massif formation is an unfavorable factor for myrmekitization. The latter is most clearly developed in rocks in which primary plagioclase is replaced by potash-soda feldspar, with an arbitrarily different orientation of both minerals.

The author agrees with D.S. Korzhinsky (1953b), who believes that the formation of reaction albite with myrmekitic intergrowths is the result of replacement of potash-soda feldspar by plagioclase. However, such an explanation of myrmekitic intergrowths cannot be considered as comprehensive. From examples which follow it may be seen that the formation and quantity of myrmekitic intergrowths depend also on the different orientation of the potash-soda feldspar being replaced, and that of the replacing plagioclase.

In granites of Verkhne-Omchansky, Urchano-Buralkitsky, Olchano-Anmanmandzhinsky, and mainly in Tenkeliysky massif, albite, which develops at the joints of potash-soda feldspar, replaces part of the grains of the latter, acquiring the orientation of the mineral being replaced, and combining with perthitic intergrowths. The other part of the grains is replaced under conditions of different orientation. In the latter case albite usually contains minute myrmekitic intergrowths (fig. 4).

FIGURE 4. Medium-grained biotite granite. Tenkeliysky massif. X150. Thin section 140.

At places in rocks of the same massifs metasomatic perthitic intergrowths partially replace the differently oriented adjacent grain of the potash-soda feldspar. Minute myrmekitic intergrowths appear in them. Myrmekites are common in those grains of a group of grains replacing the same grain of potash-soda feldspar, and which are differently oriented than the feldspar being replaced. In thin section 49/98 (fig. 5) a grain

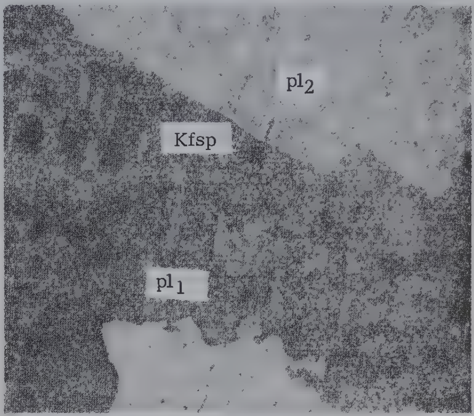

FIGURE 5. Medium-grained biotite adamellite. Tenkeliysky massif. X90. Thin section 49/98.

of potash-soda feldspar is replaced by plagioclase Ab. 79 (pl_1), which acquires the orientation of the lattice (and indicatrix) close to the orientation of the mineral being replaced, and does not contain myrmekitic intergrowths (angles between the axes of the indicatrices $\gamma_1 \wedge \gamma = 6^\circ$, $\beta_1 \wedge \beta = 7^\circ$, $\omega_1 \wedge \omega = 4^\circ$). Potash-soda feldspar is replaced by another grain of plagioclase Ab. 71 (pl_2) under different orientation of their indicatrices (the angles between the indicatrix angles are $\gamma_2 \wedge \gamma = 20^\circ$, $\beta_2 \wedge \beta = 20^\circ$, $\omega_2 \wedge \omega = 11^\circ$). There is a reaction rim of albite with myrmekites at the boundary of these grains.

An analogous phenomenon is observed in thin section 163-2 (fig. 6). The grain of potash-soda feldspar (Kfsp) is replaced by several grains of plagioclase. Plagioclase Ab. 86 (pl) has an orientation close to that of potash-soda feldspar (angles between the identical axes of indicatrices are $\gamma_1 \wedge \gamma = 8^\circ$, $\beta_1 \wedge \beta = 9^\circ$, $\omega_1 \wedge \omega = 8^\circ$) and does not contain myrmekitic intergrowths. While the orientation of plagioclase Ab. 92 (pl_2) and plagioclase Ab. 90 (pl_3) strongly differ from the orientation of the potash-soda feldspar (angles between the indicatrix axes are $\gamma_2 \wedge \gamma = 24^\circ$, $\beta_2 \wedge \beta = 72^\circ$, $\omega_2 \wedge \omega = 78^\circ$ and $\gamma_3 \wedge \gamma = 68^\circ$, $\beta_3 \wedge \beta = 86^\circ$, $\omega_3 \wedge \omega = 90^\circ$) and the plagioclase contains myrmekitic intergrowths, the amount of which is higher in pl_3. It may be seen here that pl_2, at the joint with another grain of potash-soda feldspar ($Kfsp_2$) under conditions of still greater difference in orientation of indicatrices, contains more myrmekitic intergrowths of different orientation.

The following conclusions can be drawn

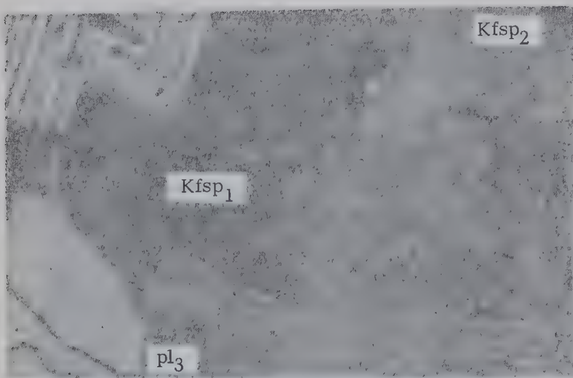

FIGURE 6. Medium-grained biotite adamellite (minor outcrops of granitoids). X90. Thin section 163-2.

from 42 measurements of plagioclase rims which replace the potash-soda feldspars:

1) Under conditions of equal basicity of plagioclases, the higher the amount of myrmekitic intergrowths in the rims, the more difference there is between the orientation of the plagioclase being replaced and the replacing plagioclase.

2) The internal part of the rims almost always differs from the external part by its slightly higher basicity and, as a rule, contains more myrmekitic intergrowths.

3) The basicity of metasomatic plagioclase generally increases with the depth of formation of massifs.

During the described process of autometasomatic alteration of granitoids, sodium and some calcium are introduced, while potassium, primarily, is removed. Autometasomatism of this kind can be called calcium-sodium metasomatism, and the massifs characterized by such type of rock alteration can be referred to the zone of calcium-sodium autometasomatism.

Replacement of Potash-Soda Feldspar by Acid Plagioclase under Condition of Identical Orientation of Minerals

With the decrease of depth of formation · massifs, more metasomatic replacement of potash-soda feldspar by albite and oligoclase is developed in rocks. These minerals acquire the crystallographic orientation of the replaced feldspar. Simultaneously the role of replacements decreases under conditions of arbitrary mutual orientation of these minerals.

Albitization is encountered predominantly in rocks of the Verkhne-Omchansky, Urchano-Buralkitsky and Olchano-Anmanmandzhinsky massifs. On a far smaller scale albitization of potash-soda feldspar is observed in rocks of the Tenkeliysky massif.

Practically no metasomatic albite occurs in granodiorites of the Gerkules massif.

The most usual form of potash-soda feldspar replacement by albite is the formation of replacement perthites, where most frequently the newly formed albite grows over the previously existing perthitic intergrowths of dissociation, or over the relicts of plagioclase in grains of potash-soda feldspar, and also develops along the cleavage (010) and (001) of the latter, with formation in places of chessboard albite.

A rim of chessboard and usually acid plagioclase and albite (fig. 7) is observed frequently in grains of potash-soda feldspar, similar to that recorded for ovoids in rapakiwi-granites (Velikoslavsky, 1953). In separate cases the rim is represented partially by the earlier oligoclase,

FIGURE 7. Medium-granular porphyritic leucocratic biotite granite, Verkhne-Omchansky massif. Rim of metasomatic albite (alb) on the grain of potash-soda feldspar (Kfsp). X10. Thin section 8b.

and partially by the later chessboard albite.

As a result of replacement of potash-soda feldspar by acid plagioclase, amount of the latter increases in granitoids with the decrease in depth of formation of massifs, and is 15 to 20 percent of the rock volume in granites of the Verkhne-Omchansky massif.

An increase of the amount of replacement perthites in potash-soda feldspars from 0. 2 to 5 percent in the Gerkules massif to 40 or 45 percent in the Verkhne-Omchansky massif confirms that sodium metasomatism increases with the decrease in depth of formation of massifs.

It is evident from 42 measurements of acid plagioclase and potash-soda feldspar, replaced in the described manner, that the replacing and replaced feldspars have an identical position of cleavage planes (meaning that the orientation of crystalline lattices of both minerals coincides) and an approximately equal position of the identical axes of their indicatrices. Consequently, the character of replacement is the same as the character of the earlier-described replacement of primary plagioclase by potash-soda feldspar in the zone of potassium-sodium autometasomatism, and identical with the character of replacement of potash-soda feldspar of ovoids by oligoclase in rapakiwi-granite (Velikoslavsky, 1953). It follows also from these measurements that: a) the basicity of the replacing plagioclase increases with the depth of formation of massifs, but is never higher than Ab. 71. b) The basicity of the replacing plagioclases increases with the increase of their grain size. c) The acid plagioclase forms twins according to the albite and Carlsbad laws.

This type can be called sodium metasomatism of perthite formation, since basically the formation of replacement perthites is the characteristic factor. It is encountered mainly in granites of those massifs where, during the first stage of autometasomatism, the replacement of primary plagioclase by potash-soda feldspar develops, and when both feldspars have an identical orientation (fig. 8). Therefore, in the future the zone of sodium-potassium metasomatism will mean a zone in which the rocks are altered by both the sodium-potassium metasomatism of the first stage and by sodium metasomatism of the second stage.

Sodium was introduced into the rock during metasomatic formation of acid plagioclase and albite, while mainly potassium was removed. Calcium was removed due to albitization of primary plagioclase, as well, evidently as magnesium and iron.

Formation of Quartz-Albite Rocks as the Result of Complete Metasomatic Replacement of Potash-Soda Feldspars by Albite

The elevations of some watersheds within the Verkhne-Omchansky massif and separate insignificant areas on the watersheds within the Olchano-Anmanmandzhinsky massif are represented by quartz-albite rocks, which consist of 55 to 65 percent albite and 35 to 45 percent quartz. Being located hypsometrically higher than the granites of the sodium-potassium zone of metasomatism, these rocks consist of minerals which crystallized from the lowest-temperature solutions of the sodium autometasomatic stage. Albite is represented more frequently by two, sometimes by three, and even by four varieties, which formed at different times.

The earliest of these to occur in places is primary, entirely albitized, plagioclase. It contains a great number of various secondary products and sometimes has a barely perceptive wavy extinction, as distinctive features.

Next, in time of formation, is a variety of albite with continuous medium and thin twin bands. In quartz-albite rocks of the Verkhne-Omchansky massif this variety of albite is contained in an insignificant amount, while it predominates at spots in quartz-albite rocks of the Olchano-Anmanmandzhinsky massif, and in dikes of quartz-albite rocks in deep-seated parts of the Verkhne-Omchansky massif.

Chessboard albite is still later in time of formation. It rarely occurs in quartz-albite rocks of the Verkhne-Omchansky massif, and is usual in quartz-albite rocks of Olchano-Anmanmandzhinsky massif.

Finally, albite with thin, discontinuous, frequently wedging-out twin bands, and with areas of incipient chessboard structure, is the latest and lowest-temperature variety. This variety of albite is widespread mainly in quartz-albite rocks of the Verkhne-Omchansky massif, and occurs in the Olchano-Anmanmandzhinsky massif.

All varieties of albite except the last occur also in rocks of the lower sodium-potassium zone of autometasomatism.

The formation succession of these varieties of albite may be illustrated by the following examples.

A major grain of oligoclase (Ab. 86) with antiperthites has a rim of chessboard albite (Ab.95), formation of which occurred either under conditions of albite overgrowth on oligoclase, or due to recrystallization of the latter.

In quartz-albite rocks of the Olchano-Anmanmandzhinsky massif, grains frequently occur having central parts of albite with uniform, continuous twin bands of medium width, while the peripheral parts of the grains consist of later albite with discontinuous wedging-out individuals.

It may be seen in one thin section of quartz-albite rock from the Verkhne-Omchansky massif that albite with continuous twin bands (or primary albitized plagioclase) contains minute myrmekitic intergrowths at the joint with albite, which is characterized by discontinuous twin bands. These intergrowths could have appeared in earlier albite during the time when the place of the second albite was still occupied by potash-soda feldspar.

In general, the basicity of acid plagioclases decreases in time with the decrease in temperature of postmagmatic solutions. Thus, if the first two varieties of acid plagioclases are frequently represented by oligoclase in rocks of the sodium-potassium metasomatic zone, then the third variety is almost always represented in the same zone by albite (chessboard). Albite with discontinuous twin bands occurs only in quartz-albite rocks formed at lowest temperature.

Formation of albite in quartz-albite rocks formed the same way as oligoclase and albite in rocks of the underlying soda-potash zone of autometasomatism, i. e. mainly by replacement of potash-soda feldspar both having identical orientation of the crystalline lattices.

During the formation of quartz-albite rocks, sodium was introduced, while potassium and calcium were removed. Consequently, this variety of autometasomatic alteration of granitoid rocks can properly be called sodium metasomatism. Parts of massifs where this process is considerably developed can be called the zone of sodium autometasomatism. In the case under consideration this zone evidently overlaps the zone of albite formation as a result of the displacement of sodium during the stage of predominantly potassium autometasomatism.

More than 30 measurements were performed on chessboard plagioclases and albites[4] with the purpose of determining the twin laws of metasomatic albites and oligoclases, and for comparison with chessboard plagioclases in granitoid massifs formed at great depths, where the mode of formation of most of the plagioclases is not clear. The following conclusions can be made relative to the formation of chessboard albites and plagioclases:

1) The basicity of chessboard plagioclases increases with the depth of formation of massifs.

2) During the early stages of formation, i. e. in replacement perthites, the basicity of chessboard plagioclases is determined by numbers not higher than Ab. 90-88.

3) The following twin laws of metasomatic chessboard albites and oligoclases have been established for the Verkhne-Omchansky and Urchano-Buralkitsky massifs:

In cases when the twinning of one system of twin bands is developed according to the pericline law, another system of twins is developed with the composition plane (010), where the axis [010] is the twinning axis for both systems and differs by 2^{o}-4^{o} from $\perp$ (010). By conventional measurements twinning with the composition plane (010) can be considered as albite twinning.

In cases where one system of twin individuals grows together by twinning according to the Carlsbad law with the composition plane (010), another system of chessboard plagioclase individuals intergrows with the composition face parallel to the rhombic section, recognizing that the pole RS deviates by 5^{o}-15^{o} from the twin axis [001] (for albites and albite-oligoclases).

It is necessary to mention that the albite and Carlsbad twins develop parallel to the cleavage (010) of potash-soda feldspar, while the pericline twins and intergrowths parallel to the rhombic section, observed with the Carlsbad twinning, develop parallel to the cleavage (010), recognizing that the twin seams are parallel to the cleavage planes of the replaced potash-soda feldspar. The combination of intergrowths parallel to the rhombic section and to the composition section (010) in Carlsbad-law twins is inherent predominantly in chessboard albite formed last, including albite with inconsistent twin bands.

In rocks of the Tenkeliysky massif almost all measurements of chessboard plagioclases, including those which are clearly of metasomatic origin, indicate that one system is formed according to the albite law, and another according to the pericline law. Only in one case, in the central part of a large grain of chessboard plagioclase, the periphery of which is twinned according to the albite and pericline laws, twinning of chessboard plagioclase is developed according to the albite and Manebach laws.

In most parts of the chessboard plagioclases of Gerkules massif one system of twins is united according to the albite law, and another according to the pericline law. Only in a single case twinning of chessboard plagioclase was formed according to the Manebach and albite-esterelian laws.

For illustration of the above-mentioned relationship a diagram is constructed to represent the position in space and the consecutive order of manifestation of morphological varieties of

[4] Most of the measurements on chessboard plagioclases, as well as feldspars, were performed by V.M.Vilesova.

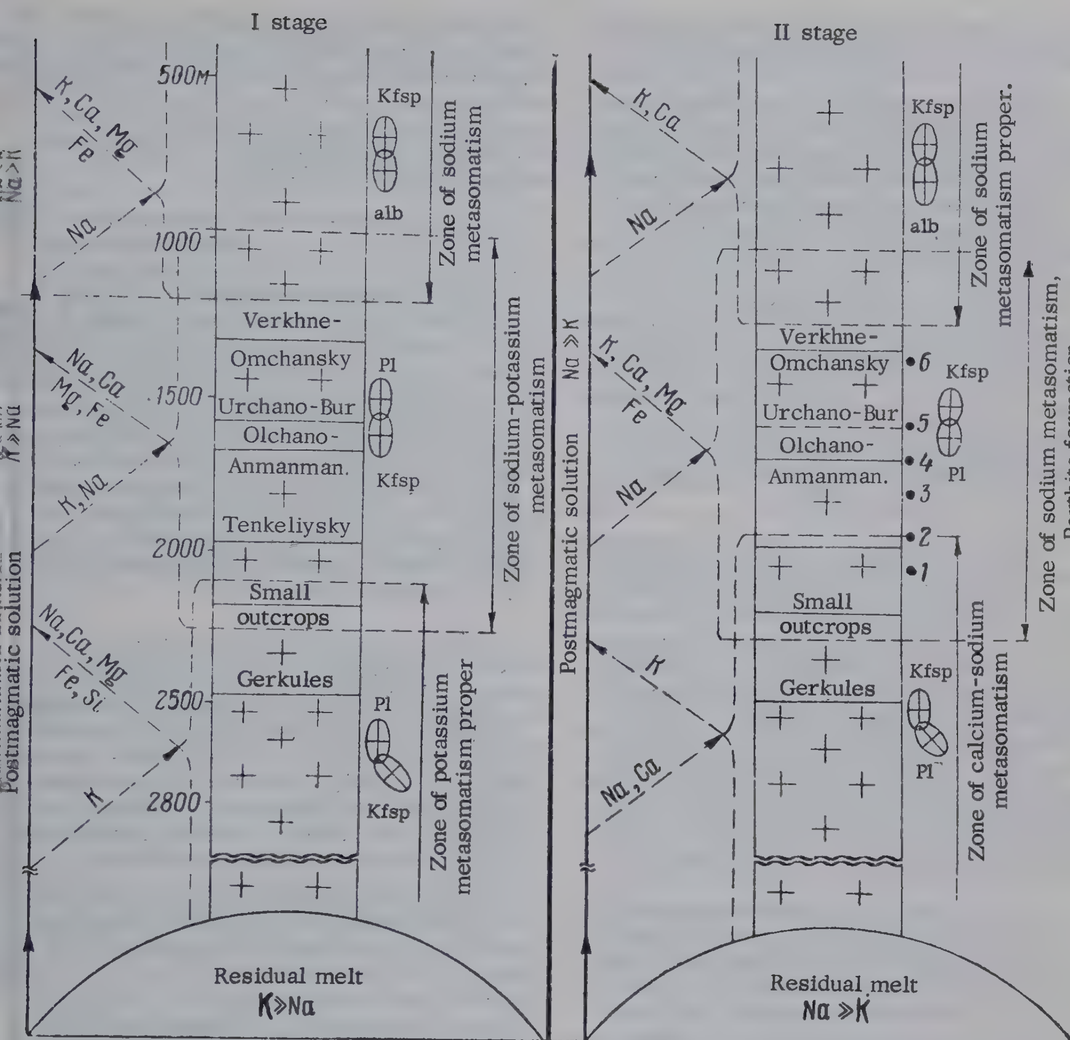

FIGURE 8. Diagram of distribution in space and consecutive order of manifestation of different morphological varieties of alkaline autometasomatism.

First stage — predominantly potassium autometasomatism.
Second stage — predominantly sodium autometasomatism.

Replacement of one crystal of feldspar by another under conditions of identical (positions of ellipses in upper and middle parts of the diagram) and arbitrary (position of ellipses in the lower part of the diagram) orientation of minerals.

1) Approximate position within the zone of sodium-potassium metasomatism of tin mineralization associated with Gerkules massif; 2) with minor granite outcrops; 3) with the massifs of Tenkeliysky; 4) Olchano-Anmanmandzhinsky; 5) Urchano-Buralkitsky; 6) Verkhne-Omchansky.

alkaline metasomatism (fig. 8). The left part of the diagram represents the position in space of the morphologic varieties of metasomatic replacement of one kind of feldspars by other feldspars during the stage of predominantly potassium autometasomatism. The right part of the diagram displays similar relations characteristic of the predominantly sodium autometasomatic stage.

The left side of each columnar section indicates those elements introduced into the rock and those removed from the rock (probably in the form of oxides). The right side indicates the character of replacement of the early feldspars by the late feldspars.

Summarizing the results of all rock alterations

in the massifs studied, the process of autometasomatism may be represented as follows:

During the first stage of rock alteration the postmagmatic solutions move through pores and small fissures in crystallized, cooling granites, the composition of which has been determined by the processes developing in the magma. As the solutions move upwards they cool and the solutions are no longer in equilibrium with the enclosing rocks. Potassium, contained at highest concentration in these solutions, is the first to react to the decrease in temperature and is precipitated, entering into the composition of potash-soda feldspar, which replaces metasomatically the primary minerals – plagioclase and the dark-colored minerals. During this replacement the crystalline lattices of replacing minerals and minerals being replaced are oriented in a different way.

Further movement and cooling of the solution causes a greater transfer of potassium into the rock. But the relatively increased concentration of sodium in solution is evidently a favorable factor for partial replacement of potassium by sodium in primary plagioclases. Albitization of plagioclase probably precedes its replacement by potash-soda feldspar. The last replacement proceeds in such manner that the orientations of crystalline lattices of the feldspars being replaced and that of the replacing feldspar coincide, i. e. there is a substitution in the crystalline lattice of potassium for sodium and residual calcium (ionic exchange).

On further movement upwards the solution is more and more depleted in potassium and enriched in sodium. This results in precipitation of sodium from the solution. Albitization of primary plagioclase takes place, and there is a partial formation of metasomatic albite, which replaces potash-soda feldspar, with preservation of identical orientation of the mineral being replaced and the replacing mineral.

In such manner, the change of potassium metasomatism to sodium metasomatism during the stage of predominantly potassium autometasomatism may be explained by a) the increase of concentration of sodium in hydrothermal solution as the solution moves upwards due to the removal of sodium from the rocks of deeper parts of massifs, and b) reduction of solubility of sodium as the solution penetrating the rocks cools.

During the second stage alkaline autometasomatism the postmagmatic solutions flow through the pores and small fractures in granites, the composition of which depends on magmatic processes, as well as on alteration of rocks during the first stage of the autometasomatism. As the solution moves upward it cools and sodium contained at highest concentration in solution of the second stage begins to precipitate. Acid plagioclase is formed, frequently with myrmekitic intergrowths, which forms rims on grains of the primary plagioclase, and replaces grains of potash-soda feldspar adjacent to the latter at an orientation of the lattice of acid feldspar different from the orientation of the replaced feldspar.

The metasomatic process develops in the zone of calcium-sodium metasomatism, which approximately coincides in space with the zone of potassium metasomatism proper. In such manner, the replacement of potash-soda feldspar by metasomatic plagioclase takes place in the same rocks in which a similar replacement of primary plagioclase by potash feldspar occurred earlier. Evidently, the high temperature of postmagmatic solutions causes replacement of the earlier-formed minerals by later minerals by later minerals at different orientation of the crystalline lattices of all these minerals. Such a conclusion agrees with D. S. Korzhinsky (1953a) on the high-temperature conditions of myrmekite formation.

Further upward movement of the solutions, which is accompanied by decrease of temperature and by increase in the difference between the composition of rocks and solutions, causes more intensive replacement of potassium by sodium with the formation of oligoclase and albite, which metasomatically replace potash-soda feldspar. But under these conditions the orientations of crystalline lattices of minerals are already becoming close, or coincide.

Such a process of rock alteration is observed in the zone of sodium metasomatism of perthite formation. The boundaries of this zone approximately coincide with the boundaries of the sodium-potassium metasomatic zone of first-stage alkaline autometasomatism. Consequently, replacement of primary plagioclase by potash-soda feldspar, as well as the reversed replacement of the latter, with formation of identically oriented crystalline lattices in both minerals, takes place in the same rocks.

The consecutive upward advancement of the solution causes further transition of sodium into the rock, the replacement of potash-soda feldspar by albite, and total albitization of the primary plagioclase, thus forming quartz-albite rocks.

With the temperature decrease of solutions in time, different forms of albite arise. A similar alteration of granites is observed in the zone of sodium metasomatism proper, the boundaries of which coincide with the boundaries of the sodium metasomatic zone of the first stage.

Association of Tin Mineralization with the Zone of Sodium-Potassium Metasomatism

Tin mineralization, associated with the mas-

sifs studied, is represented by tourmaline-bearing veins of different composition. These veins occupy different positions with respect to the contacts.

Tin mineralization associated with the Gerkules massif is located in hornstones in the exocontact zone of the southern part of the massif; inside the massif hydrothermal formations are extremely rare.

Two tin-bearing areas are known in the region of the massif: in the basin of the upper course of Siliptsovy Creek, 6 km south of the massif, and the lower basin of Tarym Creek, 8 km southwest of the massif. In alluvium of the left lower tributaries of Tarym Creek the content of cassiterite reaches 600 g/m^3, and of scheelite 100 g/m^3. Cassiterite is associated here with tourmaline-quartz veins, and it, as well as tourmaline, occurs in large black crystals. Cassiterite and scheelite also make up part of thin ore veinlets in joints within hornfels. Tin content in veinlets is not more than 0. 5 percent.

Let us remember that granodiorites of Gerkules massif exhibit high-temperature autometasomatic alteration inherent to the zone of potassium and calcium-sodium metasomatism proper. Consequently, the sodium-potassium metasomatic zone is located higher in the eroded part of the massif. (At present this zone, together with tin mineralization, is located in the exocontact). This is confirmed by replacement of plagioclase by the potash-soda feldspar, with identical orientation of minerals in older contact-metamorphic diorites of some stocks, located 6 or 7 km south of the massif under consideration.

Tin mineralization is associated with minor outcrops of granitoids in the form of separate grains of cassiterite in alluvium, and insignificant amounts of tin in tourmaline quartz veins emplaced within the exocontact zones. Tin-bearing veins were not discovered in the granitoid outcrops. The most lasting low-grade tin contact in alluvium, however, is associated with some remote streams eroding these granitoids. Tin mineralization associated with small outcrops of granitoids is interrelated in the same way as in the Gerkules massif. The only difference is that tin mineralization is present here not only in the remote, but also in the nearby, areas of the exocontact.

Autometasomatic alterations of small granitoid outcrops are also in the high-temperature range, inherent mainly to the zones proper of potassium and subsequent calcium-sodium metasomatism. Therefore, it may be concluded that the zone of sodium-potassium metasomatism is located in the exocontact areas of these granitoid bodies. This may well be seen on the right bank of the upper course of Tamzlikar Creek, where a stock paleoandesites is present. Parts of this stock, remote from granitoids, consist of almost equal portions of plagioclase Ab. 45-55 and hornblende. On the other hand, in parts of the stock located in the immediate vicinity of the granitoid outcrops, an intensive albitization of plagioclase (up to Ab. 80-75) has been recorded, and in places has been completely replaced by potash-soda feldspar, with identical orientation of the crystal lattices of both minerals. Rock altered in such a way consists of potash-soda feldspar, hornblende, and an insignificant amount of quartz. Consequently, here also the coincidence of tin mineralization within the zone of sodium-potassium metasomatism has been recorded.

Tourmaline-quartz, tin-bearing veins located in the exo- and endocontacts of the massif are associated with the southern part of the Tenkeliysky massif. The most interesting veins are characterized by an extreme non-uniformity of mineralization along the strike, as well as down the dip. Cassiterite and tourmaline in these veins are high-temperature formations.

Metasomatic alterations of rocks in the southern part of the Tenkeliysky massif, as has been already mentioned, bear more features inherent to lower temperatures than in the case considered above. Here, besides the metasomatic replacements characteristic of rocks in the zone of potassium and calcium-sodium metasomatism proper, replacements are developed inherent to the zone of sodium-potassium metasomatism. Thus, the character of metasomatic rock alteration indicates the presence of a potassium metasomatic zone in the upper part, and of sodium-potassium metasomatism in the lower parts. Tin mineralization coincides in space with the lower part of the latter zone.

In the Olchano-Anmanmandzhinsky massif numerous tourmaline-quartz veins are recognized, emplaced predominantly in granites and rarely in exocontact areas. Some of these veins in the endocontact zone contain small (up to 0. 10 percent) amounts of tin. There is usually much tourmaline in veins, but it is represented by a less high-temperature variety than in veins of the Tenkeliysky massif. Cassiterite here is dark brown and sometimes forms intergrowths with quartz and tourmaline.

It is well to be reminded that granites and adamellites of the Olchano-Anmanmandzhinsky massif are characterized by higher-temperature forms of replacement of one kind of minerals by the others. Replacement of earlier feldspars by later feldspars develops here predominantly at identical orientation of crystalline lattices in minerals. Alteration of granitoids in the Olchano-Anmanmandzhinsky massif indicates the lower half of the sodium-potassium zone of metasomatism. Therefore, in this case there is also a coincidence in space of tin mineraliza-

tion with the zone of sodium-potassium metasomatism, mainly with its middle part.

Characteristic of the Urchano-Buralkitsky massif are veins emplaced in granites, numerous and various in composition. Considerable concentrations of tin are associated with the tourmaline-quartz veins, containing small amounts of yellowish-green and blue (under the microscope) tourmaline. With the exception of the usual quartz, tourmaline, and brown cassiterite, there are small amounts of sulfides and chlorite in the veins of this massif. A replacement of one kind of feldspars by the others is observed here in granites, under conditions of coinciding orientation of the crystalline lattices of minerals, inherent to the zone of sodium-potassium metasomatism. There is also a coincidence in space of tin mineralization with this zone, predominantly with its middle part.

Chlorite-quartz and tourmaline-chlorite-quartz veins, with small amounts of sulfides, brown (green and blue under the microscope) tourmaline, and cassiterite are characteristic of the Verkhne-Omchansky massif. The veins are located exclusively inside the massif. The tin-bearing veins are associated with more deeply eroded parts of the massif.

There are no tin-bearing veins in quartz-albite rocks which formed at lower temperatures. They are also absent in the exocontact parts of the massif.

Within the boundaries of Verkhne-Omchansky massif tin mineralization is mainly associated with the upper part of the sodium-potassium metasomatic zone.

Studies of tin mineralization in relation to alkaline metasomatism of the enclosing rocks permits the following conclusions:

1) All shows of tin mineralization are spatially located in the zone of sodium-potassium metasomatism independently of the position of this zone with respect to the contacts of the massif.

2) Tin mineralization of the highest temperature is associated with massifs where the autometasomatic alteration of granitoids is of highest-temperature character. This mineralization is associated with the lower parts of the zone. In other words, tin-bearing veins of different formation temperature correspond to different parts of sodium-potassium metasomatism. (An approximate position of tin mineralization within the zone of sodium-potassium metasomatism is shown in Figure 8.)

3) Thus, it is possible to determine, with a fair degree of certainty, the character and location of tin mineralization with respect to the contacts, taking into consideration the character of autometasomatic alteration of granitoids, according to the forms of replacement in rocks of the tin-bearing massifs of one kind of minerals by other minerals. This circumstance allows us to use the phenomena of autometasomatic alteration of granitoids in prospecting for tin.

Forms of autometasomatic alteration of granitoids in tin-bearing massifs of the same age (Upper Cretaceous) have been considered in this paper. The relative depths of massif formation are determined on the basis of the fact that the vertical movements of the earth's crust, which resulted in formation in this region of intermediate folds, had an identical trend of movement before and after the formation of massifs.

The difference in depths of formation of massifs causes the difference in temperatures of alteration of granitoids by postmagmatic solutions. In other words, separate massifs can be examined as different sequences of the measomatic columnar section with temperature and pressure gradient.

Autometasomatic rock alteration is produced by alkaline postmagmatic solutions of the highest temperature. Under these conditions potassium metasomatism develops in all cases earlier than sodium metasomatism. This fact allows us to outline two stages of alkaline metasomatism.

Highest-temperature solutions of both stages of alkaline metasomatism result in such metasomatic replacement of one kind of feldspars by the others, under which the replacing minerals acquire the orientation of the crystalline lattice different from the orientation of the minerals being replaced. During the earlier stage of predominantly potassium autometasomatism areas form with monzonitic structure. During the next stage of predominantly sodium metasomatism albite and oligoclase with myrmekitic intergrowths form in the same rocks. It has been established that the amount of myrmekitic intergrowths depends not only on the basicity of plagioclases, but, under conditions of equal basicity, it depends also on mutual orientation of crystalline lattices of the replaced and replacing feldspars.

With decrease of temperature of solution, i. e. with decrease of depth of formation of massifs, replacement of the earlier feldspars by the later feldspars dominates. During the process of this replacement the replacing minerals acquire the orientation of crystalline lattices of the replacing minerals by the replacement in the crystalline lattice of one alkali metal by another. Also, in those rocks where during the first stage of the alkaline metasomatism there is replacement of the primary

plagioclase by potash-soda feldspar, there is a similar replacement of the potash-soda feldspar by oligoclase and albite during the second stage.

In the light of the established regularities of succession in space of different types of mutual replacement of feldspars, the opinion expressed by S. A. Rudenke (1954) about the lowest temperature range of perthite, and replacement anti-perthite formation at different orientation of crystalline lattices of the replaced and replacing feldspars, is erroneous. It has been demonstrated that such replacement takes place at the highest temperature range.

During the metasomatic replacement of potash-soda feldspar by chessboard albite in rocks of the Verkhne-Omchansky massif, the following twin laws prevail: If in one direction twins are formed according to the pericline law, then in the transverse direction the individuals almost always twin according to the albite law.

If in one direction the system is forming twins according to the Carlsbad law, intergrowing parallel to (010), then in transverse direction it grows parallel to the rhombic sequence, the pole of which does not entirely coincide with the twin axis [001].

All shows of tin mineralization genetically related to the massifs investigated are associated with the zone of sodium-potassium metasomatism, i. e. in those areas where in rocks the earlier feldspars are replaced by the later, at identical orientation of the crystalline lattices of minerals. Tin mineralization of higher-temperature formation is associated with the massifs formed at greater depth and is located in the lower part of this zone of metasomatism. Massifs formed at the least depth are characterized by the mineralization of the lowest temperature range, which is located in the upper part of the same zone.

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RECRYSTALLIZATION DURING THE FORMATION OF CRYSTALLINE QUARTZ VEINS[1]

by

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• *translated by Royer and Roger, Inc.* •

ABSTRACT

Recrystallization plays a large part at all stages of formation of different quartz veins, particularly crystalline ones. The veins contained in quartzites and other monomineral quartz rocks commonly originate from recrystallization when solutions infiltrate tectonically disrupted zones. In other cases, massive quartz veins have recrystallized with the formation of mixed, pole-like aggregates, or glassy types of quartz. Recrystallization druses are sometimes formed during the later stages of veining. These can be divided into druses of the first type, formed in the host rock through quartz veins, and those of the second type, formed by collective recrystallization in the host rock. --Author.

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Recrystallization is important in the formation of crystalline quartz veins, but until recently due attention was not given to this fact. The manifestations of recrystallization are often totally ignored, although it is probable that they alone can explain a number of characteristic structural features of veins.

A detailed study of veins in recent years by a number of different research workers has shown that recrystallization was often a pilot process at different stages of their formation. This is apparent from the use of such terms as 'recrystallization veins' and 'recrystallization cavity' and 'druses of recrystallization' (Grigoryev and Kapitonov, 1953; Tokmakov, 1957).

The recrystallization of quartz crystals or aggregates of them is a special case of metamorphism and involves two principal processes: 1) the combining of small grains into large crystals, and 2) the breaking down of large crystals with the formation of a dense aggregate of small grains. We shall consider, chiefly, recrystallization of the first type, since it is this that determines some of the most characteristic and important features of the structure of many crystalline quartz veins, especially in view of the fact that this subject has not been sufficiently dealt with in scientific literature Recrystallization of the second type has been considered in a fair amount of detail in a number of publications (Adams, 1934; Vertushkov, 1946, 1953).

The chemical composition of quartz aggregates does not change during recrystallization, but there are important textural and structural transformations with a definite, progressive increase in grain size, right up to the stage of formation of faceted quartz crystals. Recrystallization differs in this way from metasomatism, in which the chemical composition of the rocks is changed. On the other hand, there are certain points of similarity between recrystallization as a process of formation of crystalline veins, and metasomatism. Both processes are most intense in tectonically disrupted rocks. They both occur with the definite participation of essentially water solutions, either liquid or gaseous in form. In both cases the grains grow in the solid medium, and eventually very large, in place enormous, crystals are produced (Tokmakov, 1957).

It has been pointed out many times by investigators that the vein filling of crystalline quartz veins originated separately in time from the later crystal-bearing cavities, and quartz crystals forming in the cavities, and other complex paragenetic minerals forming at the final stages of activity of the solutions. Hence it is more to the point to consider first evidence in favor of recrystallization during the formation of the actual body of quartz veins.

Monomineral or practically monomineral quartz veins may occur only as the result of the recrystallization of pure quartz rocks, i. e., quartzite, quartz sand, etc. It is therefore natural to look for veins primarily formed as recrystallization veins in these rocks alone. The Upper Aldan crystal-bearing region, where all the veins occur in quartz interbedded with various gneisses and Precambrian crystalline schists (Tokmakov, 1957) is particularly favorable. The veins here occur in clearly defined superimposed fractures or fracture systems mostly represented by schist granulation zones without any visible shifting along them. The intensity of the quartz mineralization is usually a direct function of the degree of tectonic disturbance within the zones. In many deposits, where there are only a few fractures a small distance from each other, quartz veins

[1] Translated from O yavleniyakh gerekristallizatsii gri formirovanii khrystalenosnykh kvartsevykh zhil: Mineralogichesky sbornik, Lvovskogo geologicheskogo obshchestva, no. 13, 1959, pp. 149-157.

do not form at all, or else form very thin veins along the fractures.

On the basis of their points of contact with the enclosing rocks, all crystalline quartz veins of the Upper Aldan can be divided into two categories: 1) veins with indeterminate, diffuse points of contact, and 2) veins with clearcut points of contact. The first type is usually embedded in almost monomineral quartzite, while all other rocks, including polymineral quartzites, contain well-developed veins of the second type. Where the vein is embedded in thickly interbedded rocks of different composition, the nature of the contact is correspondingly altered. For example, the upper part of the vein zone in the Kholodny deposit is contained in lamellar sillimanite quartzite, and below in solid, almost monomineral quartzite. The nature of the contacts of the quartz veins also change accordingly; the contacts are more clearcut at the top of the deposit, whereas underneath they are less distinct, sometimes completely diffuse, and give the impression of a very gradual change from the quartz to the enclosing quartzite. In the western part of the deposit there is a thick layer of essentially feldspar gneiss in the quartzite, and on the boundary the quartz mineralization, shown strikingly at all the upper horizons, ceases abruptly.

The study of prisalband vein sections with diffuse contacts shows that there is usually a thin zone of incomplete recrystallization in quartz crystals. Microscopic investigation shows that within this zone they usually lose their cataclastic or granoblastic structure. The quartz grains here have a smooth extinction and a characteristic elongated or isometric outline with panidiomorphic limitations. In the body of these veins there commonly are blocks of partially recrystallized or completely unrecrystallized quartzite, which generally have "smoothed out", rounded outlines.

Observations on the mineral composition of the veins are of great interest. Quartz veins injected among almost monomineral quartzites commonly contain appreciable concentrations of fine, rounded zircon crystals, which are also present in the enclosing rock in about the same quantity.

A similar situation is noted in the distribution of feldspar occurring in the form of separate xenomorphic grains both in the enclosing rock and in the vein quartz. In quartz veins lying outside the monomineral quartzites, there are hardly any fine round zircon crystals, but hydrothermal minerals such as rutile, anatase, more rarely tourmaline, and certain others, are usually secondary components of the veins. There are hardly any new grains of feldspar anywhere here, but friable kaolin concentrations are present instead.

Enclosing quartzite often contains pegmatite veins and thin seams of essentially feldspar composition. Where the quartz veins intersect, these feldspar seams can be traced from the enclosing quartzite through the body of the vein in the form of distinct relicts formed by a continuous chain of xenomorphic feldspar grains (Tokmakov, 1957).

All these facts are convincing evidence that in the Aldan rocks, quartz crystal veins contained in monomineral quartzites commonly bear signs of having been formed by recrystallization in the tectonic zones. Along these zones there was first granulation of coarse-grained quartzite, and then recrystallization of the fine-grained aggregates formed into vein quartz. On the other hand, in some deposits, some of the quartz veins occur in rocks of a different composition -- sillimanite quartzite, granite gneiss and amphibolite, and in crystalline schist and gneiss. In most cases, the veins in these rocks have a rectilinear outline and distinct contacts. Especially marked is the difference in the nature of the contact at the places where a vein runs from monomineral quartzites into other rocks. These veins have evidently originated from solutions by the filling of empty spaces, as no signs of metasomatism are to be found in them.

Quartz veins occur in the more or less pronounced fractures and fracture systems which usually form the zones along which the solutions infiltrate. The free movement of solutions predetermines a greater or lesser shift of compounds migrating easily under certain conditions, such as silica or alkaline metal metasilicates of the type R_2SiO_3 or $R_2Si_2O_5$. It is evidently for this reason that recrystallization of the enclosing rock is accompanied by redistribution along the zones where the quartz veins are forming, these veins often representing a complex product of the concurrent processes of recrystallization, dissolution and redeposition of silica.

Although recrystallization quartz veins are not very widespread, because they can occur in rocks of a certain composition only, recrystallization of the actual veins themselves is evidently very common in nature. It might be thought that any quartz vein undergoes recrystallization to some degree after formation, provided the solutions still have access to it and continue to seep through fractures of different sizes in the body of the vein. This has been convincingly demonstrated by A. N. Igumnov (1951) in relation to some ore-bearing quartz veins; with regard to the crystalline veins, some of the new crystal structures occurring in them probably also owe their appearance to recrystallization.

Recrystallization of a quartz vein occurs when the solutions infiltrate chiefly through the intergranular surfaces and along fractures resulting from tectonic movements, and evidently also

from internal stresses during crystal growth and recrystallization.

The great variety of quartz textures, which often differ greatly one from the other, is characteristic of many quartz veins. The presence of texture types in one vein is sometimes due to the precipitation of consecutive generations or nucleations of crystals from the solutions, but in other cases aggregates different in texture occur as a result of the recrystallization of some of the sections of the vein.

Vein quartz, milky white or gray, is commonly represented by columnar types, which make up the entire body of the vein or some irregular parts of it. In many quartz veins in Central Kazakhstan, columnar quartz veins form a complex network in the compact quartz. The size of the individual members of the columnar aggregate varies, ranging from fine "columns" to enormous crystals a meter or more in length. In the Pamirs, lenticular and block-shaped veins with this huge columnar texture even form a curious nonindustrial type of vein (Sazhkarchenko). There are veins of this kind in the Polar Urals, Aldan and other crystal-bearing regions. In industrial veins, we also find sections with large and extra-large columnar members, which usually have their induction surfaces closely interwoven.

In many cases the veins have a layered structure, but columnar vein quartz is just as commonly an uneven crystalline aggregate with differently orientated members forming a tangled columnar aggregate. The development of columnar types of quartz near crystal-bearing cavities is especially typical, and is observed in many deposits in all crystal-bearing regions.

Parallel columnar quartz aggregates, frequently with pronounced layering crustification, may grow under conditions of free crystallization in open fractures, or where the fractures widen slightly, where the crowded crystallization of the quartz occurs.

The mechanism of formation of these aggregates has been examined in detail by D. P. Grigoryev (1954). We believe that the entangled columnar aggregates have arisen in more or less the same way as the recrystallization druses. Grigoryev also describes the formation of the druses. He writes: "This phenomenon (growth of recrystallization druses -- Ye. L.) occurs in the monomineral mass into which the solution penetrates, acting first as the solvent; then, as it is dissolved, it becomes saturated and even supersaturated with large grains of the mineral, but continues to dissolve the fine grains. In this case solution cavities are formed, the granular mass near them becomes larger in size while groups of regularly formed crystals grow in the cavity or fracture; the phenomenon gradually dies out as the mass untouched by recrystallization moves to the side" (Grigoryev, 1954, p. 190). Here the mountain crystal druses are formed at the final stages of the process and with a definite loss of substance, which is exactly the only time that the larger cavities can form. But if the loss ceases at some earlier stage, it is easy to see that entangled columnar aggregates of vein quartz will be formed instead of druses. Nevertheless, parallel columnar quartz aggregates can evidently also be formed under certain circumstances through recrystallization. This probably occurs in the same way as assumed above for the entangled columnar aggregates, but only where there is recrystallization of similarly oriented crystals primarily.

An abundance of gaseous and liquid impurities are usually found in crystals of columnar quartz, which are very close in all characteristics to the impurities in mountain crystal.

All that has been said above suggests that the origin of large and extra-large columnar, milky-white quartz in veins directly precedes the growth of mountain crystal in cavities, or that they grow at the same time through the same solutions.

Besides the formation of columnar types of quartz, recrystallization may lead to the formation of other aggregates. In particular, we believe that recrystallization sometimes produces very curious glassy types of quartz which do not have crystallographic outlines, but are marked by a uniform texture and are at times completely transparent. This type of quartz is found in various regions in the form of individual veins and lenses, but most frequently it is found as lenticular or vein-shaped segregations in granular or columnar vein quartz. Such types of quartz are glassy. At the earlier stages of transformation of this type, recrystallization occurs along the fractures in the vein quartz together with the formation of very thin seams of secondary semitransparent or transparent quartz. The seams are particularly clear against the milky white crystals. Quartz formed as a result of this partial recrystallization is marked by a very curious lenticular-stellate or seam-stellate structure (Zakharchenko, 1955).

It is also clear that in certain veins recrystallization of a similar nature occurs in minor granulation zones. For example, at the Pyramid deposit (Polar Urals) we observed individual cases of light grey semitransparent quartz which intersected crystals of earlier quartz as well as enclosing quartzites in seams 2 cm thick. These veins are apparently the result of recrystallization of finely granulated quartz along narrow, local tectonic disturbances which develop inside the mineralized zone.

The lenses and seams of glassy quartz are probably produced in the same way during con-

tinued circulation of hydrothermal solutions along fracture systems or granulation zones in quartz veins formed earlier. At the Aldan, Polar Ural and Pamir deposits, the glassy quartz forms lenses and veins in close proximity to crystalline clusters. The orientation of these deposits relative to the vein is different; quite frequently they occupy a transverse or diagonally intersecting position.

Thus, the appearance of sections of transparent quartz in a block of milky white vein quartz can also be explained by recrystallization. On this basis it should be pointed out that the relationship between transparent and milky white quartz in seams is not always as it has been described by G. N. Vertushkov (1946, 1953) for certain veins in the Urals, and that this investigator only takes the second type of recrystallization, of those mentioned at the beginning of this article, into account.

It is clear from what has been said that, recrystallization in the body of quartz veins may lead to the formation of morphologically distinct end-products such as columnar aggregates and sections of glassy quartz in veins. The reason for this is not entirely clear. It is possible that glassy quartz, particularly its ice-transparent types, originates through the prolonged treatment of intensively fractured or granulated sections by infiltrating solutions, as a result of which all the impurities are lost, while a large number of recrystallized grains acquire identical optic orientation. Consequently, the sections of ice-transparent quartz are a sort of single "crystal", generally of tremendous size, but devoid of crystallographic outline. Recrystallization of the type completes its activity with the formation of ice-transparent quartz through various textural aggregates of vein quartz.

In the later stages of formation of crystal quartz veins, recrystallization often shows up in the formation of so-called recrystallization druses, the growth mechanism of which has been considered in detail by D. P. Grigoryev and M. D. Kapitonov (1953) and D. P. Grigoryev (1954). It is true that the first of these investigators, according to the text of one of his latest publications on this subject (Grigoryev, 1954) does not relate the druses described earlier by A. Ye. Karyakin (1954) and also by Johnson and Butler (1956) to the recrystallization druses. Crystal growth in the enclosing rocks and not in the cavities is typical of these druses, the above-mentioned investigators assume. But crystal growth in the enclosing rocks occurs very rarely, and then only under certain conditions. We had occasion to observe this growth solely at the Pyramid (Polar Urals) and Sosedka (Aldan) deposits. In both cases, crystals grew in the enclosing rocks which had been converted by earlier hydrothermal processes into a flaky very porous, poorly cemented mass of irregular grains, and also of fine semitransparent or transparent crystals of quartz, frequently with perfect crystallographic contour. There need be no doubt that these rocks, given free infiltration of the solutions along fractures, were saturated with quartz-forming solutions in the same way as a sponge. The growth of crystals through collective recrystallization in such conditions can be likened, to a certain extent, to the formation of crystals in an open cavity. The druses and individual crystals of the quartz occurring in this way are in most cases poor in quality, since any impurities contained in altered basic quartz rocks remain in crystal form. Morphologically they are no different from crystals and druses which have grown freely; this shows the extreme similarity of the mechanism of their formation.

Particularly curious druses were noticed at the Pyramid (Polar Urals) deposit. Here we frequently came across bi lateral druses, one side of which grew in the cavity and the other in hydrothermally changed sericite quartzite. The crystals growing in the cavity were completely transparent, while those in the second half of the druse were full of sericite grains orientated in the same way as in the enclosing quartzite. At the dividing point between these crystals it was possible to see that they consisted of a mass of fine grains which were just like the grains of the enclosing rocks in appearance. It was only under the microscope that it was possible to determine that these grains had identical optic orientations and were part of a single crystal. The granular, quartzite-like structure of the body of the crystals was due to the presence of a mass of sericite grains between the quartz grains and those which remained in the same place when the quartzite was recrystallized into quartz crystals.

Thus, recrystallization druses may occur as the result of recrystallization of vein quartz, or as a result of the collective recrystallization of hydrothermally changed quartzite. The first are recrystallization druses of the first type, and the second, recrystallization druses of the second type.

Recrystallization druses of the first type are found in crystal-bearing cavities which on certain grounds can be called recrystallization cavities (Tokmakov, 1957). These druses are formed from the material of the quartz veins themselves and can therefore be found in any deposit where the formation of vein quartz has occurred on a large scale. It should be stressed in this connection that druses which have begun to grow through recrystallization may sometimes continue to grow as accretion druses.

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SYNGENESIS AND EPIGENESIS IN PETROGRAPHY AND THE STUDY OF MINERAL DEPOSITS(PART 1 OF 2)[1]

by

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• translated by the U.S. Atomic Energy Commission[3] •

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FOREWORD TO THE ENGLISH TRANSLATION

The author wishes to express his sincere thanks to the U. S. Atomic Energy Commission for originating this translation. The oportunity is also acknowledged to add some corrections. Readers interested in ore genesis will notice that in this paper the nature and importance of the "space duality" and the most flexible and frequently subconscious interchangeability between space and

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[1] Translated from Syngenese und Epigenese in Petrographie und Lagerstättenkunde: Schweizer Mineralogische und Petrographische Mitteilungen, v. 39, p. 1-84, 1959. The paper is an enlarged combination of two lectures presented in Zurich and in Heidelberg in August 1958. Part 2 of 2 will appear in a subsequent issue of IGR.

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[3] Review and permission to publish in IGR obtained by John K. Hartsock.

time criteria and concepts had not been fully recognized. Three newer papers listed below, offer details of this facet of the present evolution in geological thought. These papers offer also suggestions on how to differentiate between syngenetic and epigenetic mineral deposits and propose in more detail new integrated classifications of mineral deposits. The paper listed last attempts to show how the present evolution of the theories on ore genesis can be understood as a development which is complementary to, or rather a continuation of, a development or trend started, or at least strongly promoted, by the "Darwinian evolution".

1959 Syngenetic zoning in ore deposits. Proc. Geol. Assoc. Canada 11, p. 95 - 114.

1960 The copper deposits Caprichosa and Antachajra in Central Peru (with notes on ore genesis in general). N. Jb. Miner., Abh. 94, p. 390-429 (Festband Prof. Ramdohr).

1960 Some basic concepts and thoughts on the space - time - analysis of rocks and mineral deposits in orogenic belts. Fiftieth Anniv. Vol., Geol. Rundschau (Stuttgart) vol. 50, 25 p.

- - G. C. Amstutz

SUMMARY

Many vital problems of rocks and mineral deposits are presently linked to criteria for syngenetic or for epigenetic origin. Two opposite schools of thought teaching these two different modes of origin have developed with regard to the origin of such major groups of ore deposits as the Mississippi Valley type, the red-bed copper and uranium type, the native coppers in lavas, the Blind River or Witwatersand type, the porphyry copper, porphyry molybdenum or porphyry iron type, the Lake Superior iron and the Kiruna iron type, the Bushveld type, etc. It is significant that the same two patterns of thought have developed largely independently in the discussion on the origin of granites, spilites, cherts, dolomites, oil deposits, the origin of the continents, the moon craters, etc.

The syngenetic and epigenetic theories of patterns of thought are illustrated and discussed on the basis of the following groups of phenomena:

A. Sedimentary rocks and ore deposits in them.
B. Intrusive rocks and ore deposits in them.
C. Extrusive rocks and ore deposits in them.
D. Tectonic and extra-terrestrial phenomena.

A comparison of genetic criteria used in discussions on these rocks and mineral deposits and of the two patterns of reasoning showed that the subdividion into a magmatic and a metasomatic or diffusionist school is less significant and basic than is the subdivision into epigenetic and syngenetic patterns of thought. These patterns can also be found in other sciences and in all other domains of human spirit. Light is thrown on the nature and role of these and other patterns, and it is shown that their recognition and analysis will eliminate old dogmatic misunderstandings and misinterpretations.

An attempt is made, using numerous examples of genetic problems in petrography and the study of mineral deposits, to arrive at a temporary stand in regard to the different theories of today. This will be done with the aim of achieving an integrated, wholistic view, and this will necessitate moving out of the limits of the actual discipline somewhat. We will examine our theories, and methods of investigation and trends of thought, as well as consider the roots of our geological "Weltbild", bringing them into the realm of our investigations.

This last step, hardly begun in this work, will most of all require a firm knowledge of the history of the geological sciences.

The opinion is held that, even though research on geological phenomena still remains in the center of the picture, and even though our measurements and observations may be largely objective, our interpretation is never truly objective.

We project images into our theories which have nothing whatsoever to do with the logical, intellectual endeavor, and we are very often obsessed by these images. It seems to be a fact that in many respects we no longer make progress today, and no longer advance towards a more objective truth, if we do not attempt at the same time to understand these images which we project into our measurements and observations.

***

DELIMITATION OF TERMS

Epigraph: "It is not in accord with the nature of scientific research to maintain the belief in possessing the only correct theory, but rather to gradually approach closer to the truth by doubting all theories." - C. G. Jung, Welt der Psyche, 1954, p. 32.

The terms syngenetic and epigenetic designate an age relationship between a mineral, a group of minerals, a structure, texture, etc. and the host rock. Syngenetic portions of rock formations or minerals (ore deposits, are after all only rocks of a special composition, usually containing one or more minerals that can be mined at a profit), is a name only given to those rock portions or minerals which were formed simultaneously with their host rocks. By simultaneously, we mean those phases of formation which require both the same conditions for formation and almost the same period of time. With this we are for the time being limiting ourselves to the actual original formation of consolidated rocks, excluding for the moment metamorphic transformations.

Consequently syngenesis for sediments comprises sedimentation, solidification and diagenesis, and further among other things also early breccia formation or erosion and resolidification by immediately overlying loose sediments. The processes just mentioned should be classified as transition-types, which by some authors such as, for example, recently by Pantin (1958) were designated as being epigenetic. As far as examinations of complete deposits are concerned it is, however, more advisable to still include them within the syngenetic time period. With regard to igneous rocks, syngenetic formation means that the rocks or minerals were formed out of the same "magma" or "migma" as the host rocks and that this took place during a certain limitable solidification process. In the strict sense of the expressions, comagmatic or comigmatic but later eruptions can already be considered transitions to epigenetic formations and hence will often show epigenetic features. Larger rearrangements may also be regarded as transitions an epigenetic type. Perhaps the concepts of syngenesis and epigenesis may also be applied to metamorphic processes and rocks. However, one has to be careful not to use the term epigenesis automatically as an equivalent for the concept of introduction of matter - from the outside. Rather, both of these terms should be separated and defined individually.

Epigenetic formation means just the opposite. It comprises all those processes whereby a transformation with or without addition or loss of matter can be proven, i. e., a transformation during a distinctly different formation period, thereby "epichronic" or "metachronic".

It will immediately become evident that there are transitions and borderline cases, if one tries to apply the concepts "neosom" and paleosom" to syngenetic and epigenetic processes. Obviously, there is also a syngenetic "neosom", e. g., the transformations of matter which take place during diagenesis. However, it is incomprehensible why a quarrel should arise in relation to these borderline cases. As long as one states the exact facts in such borderline cases, no misunderstandings will develop and too rigid a delimitation of terms will become superfluous.

With this standpoint in mind, it is to be quite welcomed when terms are first defined. For example, Pantin (1958, pages 368-369) defines at the beginning where he draws the line between syngenetic, diagenetic and epigenetic. As outlined previously, for our purposes it will prove more advantageous though, to include diagenetic processes as well under syngenesis, even including submarine breccia formation and repeated cementations, because such processes still take place within the formation cycle per se. Consequently, we agree with the definition of Tarr (1921) and of Weeks (1957).

A comprehensive study of the literature on the development of the definition of syngenetic or syngenesis and epigenetic or epigenesis cannot be offered here. Yet, it should perhaps be pointed out that other expressions are also in use. Richardson (1921) for instance used "contemporaneous", "pene-contemporaneous" and "subsequent", when he discussed the formation period of concretions. In individual cases the general definitions of Lindgren, Holmes and Johannsen are often insufficient, of which these authors were fully aware as shown by their own applications.

While the time sequence is defined by the briefly paraphrased concepts syngenesis and epigenesis, space relationships can be described by the two terms allothigenesis and autigenesis. Autigenic refers to those components which originated in place; allothigenic refers to those components which came in as solid components from the outside. Hence, these two concepts are considerably more limited than "syngenetic" and "epigenetic", because they presuppose a certain physicochemical state. In order to describe all possibilities in relation to origin in space, we very often have to use paraphrases, especially in those cases where syngenetically or epigenetically incoming liquids or gases are involved.

"The process of geological history", however, is not to be interpreted solely as "some sort of collective action in time and plane". If we proceed to work on the space and time space without considering what other rules govern existence - the "to-be-like-that-and-not-otherwise"- of geological bodies we are just floundering about

and, in addition, lose important criteria for the determination of the location on the time-space plane itself. We at least have to take into consideration a third component, a third axis in the system: the mineralogical-chemical variability and thus the physicochemical properties of the system. The three-dimensional presentation of geological processes would substantially contribute to the clarification of genetic concepts, wherein, space, time, and physicochemical state and composition are the three parameters.

It is necessary to account for the plane and direction whereon and wherein one is traveling in this genetic coordination system. Most likely it can be considered a fact that most false genetic conclusions are simply "coordination mistakes", i. e., for example, a spatial phenomenon will be thoughtlessly connected (without criteria) with a change of time, or a change in composition. Examples of this are plentiful, and constitute the central theme of this work. For instance, how often is metasomatism ("replacement") spoken of automatically when it is evident that epigenetic changes have taken place in certain rocks. Frequently it is simply overlooked that all rocks have a certain "polymorphism"; in other words different minerals, grain sizes and grain shapes may appear although the overall chemical composition remains the same.

Before we consider the significance of the three above-named parameters in somewhat more detail, we want to introduce another group of concepts which refers to the origin of dissolved, syngenetically or epigenetically introduced substances. Allothigenetic and autigenetic define the location of the formation; other terms are used to define the origin or source of dissolved materials. If matter was supplied from below, this is referred to as an ascendant, endogenous or hypogene origin. In the opposite sense, one speaks of a descendant, exogenous or supergene origin. Therefore, the following diagram may be set up, which comprises the four basic, simple possibilities in the genesis of a rock formation or of separate components of it, e. g., an ore deposit:

A. syngenetic	I. supergene
B. epigenetic	II. hypogene

The two concepts – allothigenetic and autigenetic[4] can replace or supplement supergene and hypogene, if the determination of the location of formation of a mineral is concerned, such as for instance in the case of albite or of pyrite gold ores in sediments.

[4] Occasionally we find the following spelling: authigenic and allotigenic; however the forms autigenic and allothigenic are etymologically correct.--G.C.A.

The concepts "supergene" and "hypogene" are preferred to exogenous or descendant, and endogenous or ascendant, because they are less ambiguous and are used also in the English language. Formations formed by lateral secretion are transitional between supergene and hypogene genesis. Sometimes one also finds the terms synchronic and "metachronic". In tectonics the concepts autochthonous and allochthonous are used. Of the two expressions — autolith and xenolith, only the second word is still in general usage. Autometamorphism (e. g., autohydration) is the opposite of allometamorphism, etc.

The meaning of all these expressions, however, varies greatly from author to author, and from generation to generation. The four principle possibilities for the formation of rocks or mineral deposits are thus as follows:

A. I. Syngenetic – supergene, i. e., formation within and while the surrounding host rock is formed and substances from supergene processes are being supplied, e. g., from weathering. A good example is: placer deposits.

A. II. Syngenetic – hypogene, i. e., formation as under A. I., but with the supply coming from the interior, e. g., volcanic exhalations. An excellent example is: sulfur-gypsum-pyrite deposits on volcanos.

B. I. Epigenetic – supergene, i. e., formation later than when the surrounding host rock is formed, but by supply from supergene origin, e. g., by ground-water. An excellent example is: oxidation zones, and cementation zones within ground-water ranges.

B. II. Epigenetic – hypogene, i. e., formation as under B. I., but by supply of material from depths, e. g., from magmatic or palingenetic sources of supply. Positive examples are many mineral veins around intrusive rocks.

This classification allows further possibilities for subdivision, which should be made only after we definitely know whether we are dealing with AI, AII, BI, or BII. If deposits of magmatic derivation are concerned, we can use the divisions – intramagmatic and extramagmatic, whereby the author wishes the concept extramagmatic to be understood as a collective term for tele-, crypto-, apo- and peri-magmatic.

This division makes reference to the relationship between the location of deposition and

the mother rock of the mineralizing matter. So far it has only been used for magmatic rocks, but it might perfectly well be applied to sedimentary and metamorphic rocks. Perhaps one could use the terms intraformational and extraformational respective to sediments when it is of importance to examine material that has been dissolved and transported. This division can be used in considerations on the transport of matter by ground water or by lateral secretion, such as is for example proposed by the so-called "source bed concept" (Knight, 1957), a concept supposing syngenetic origin and epigenetic concentration.

Emphasis on genesis is contrary to several text books, which prefer a strictly formal classification to a genetic one. It should probably not have to be emphasized 60 years after the publication of Pošepný's book The Genesis of Mineral Deposits (1895) that the success of exploration for new deposits is, to a large extent, dependent on a working genetic hypothesis and that, therefore, in practical work one cannot afford to neglect genesis. Unsuccessful exploration programs, most of which are hooked up with the problem, syngenesis versus epigenesis, are numerous, due to faulty reasoning in regard to genesis (Mina Ragra, Michigan copper, etc.). This had already been stressed in 1893 (e.g., in Rickard's comments on Pošepný's work, 1893 to 1902, pages 102-192).

We shall once more refer to the suggested system of coordinates, because in our opinion illogical reasoning in genesis is most simply caused by "mixing up the coordinates" in the analysis. This dissecting and partitioning of space and the time may seem exaggerated. However, the following sections will show that many subconscious and incorrect connotations in geological terms will thereby become conscious.

If we will denote the time axis as T, the space axis as R and the axis of composition and/or physicochemical state as C, then the times t_1, t_2, t_3... or the time intervals Δt_1, Δt_2, Δt_3... at which or wherein some geological events occur, are as such independent from the places r_1, r_2, r_3... or paths and spaces Δr_1, Δr_2, Δr_3... where some geological events take place. The same holds true for the composition or the changes in composition, or the physicochemical conditions respectively c_1, c_2, c_3... or Δc_1, Δc_2, Δc_3... are not, a priori, dependent on space and time. Such dependences may exist, but are not mandatory. Seen from a mathematical standpoint, dogmatic theories always consist of a confusion between these axes or of an arbitrary or automatic decrease in the actual number of degrees of freedom. Therefore, seen objectively, the following equation could be set up for a geological phenomenon P:

$$P=f(R, C, T; \Delta r, \Delta c, \Delta t; \frac{\partial c}{\partial r}, \frac{\partial r}{\partial t}, \frac{\partial c}{\partial t}; \frac{\partial^2 c}{\partial r \partial t}) \quad (1)$$

whereby we wish to express that in order to define a geological phenomenon, knowledge of the time per se (e.g., the Precambrian), of the place (e.g., the Canadian shield), and knowledge of the composition are required, and it is also necessary to know the time intervals Δt, (during which, e.g., orogenesis has taken place), and the amount of dislocation and the eventual compositional changes. These temporal, local or compositional changes can be, but do not have to be, causally connected. The establishment of such connections finally forms the next step of an examination.

Whosoever assumes now that research in the natural sciences, in working on the above equation has fulfilled its duties, has been subject to a delusion, just like Mach, who, according to Bertrand Russel (1924 and 1926, 132) thought that "the sensation as a mental event is identified with its objects as a part of the physical world". An attempt to express the essence of a scientific theory or hypothesis Th with a simple equation would therefore, have to allow at least for a human "uncertainty factor" or a "factor of relativity", which influences observations individually and collectively. Consequently, one would have to write approximately as follows:

$$Th=f[U(R, C, T; \Delta r, \Delta c, \Delta t; \frac{\partial c}{\partial r}, \frac{\partial r}{\partial t}, \frac{\partial c}{\partial t}, \frac{\partial^2 c}{\partial r \partial t})] (2).$$

The factor U has been frequently and extensively the objective of scientific investigations. Actually, the introduction of this factor is nothing but a simplified consideration of different predicates of human knowledge, which we cannot discuss in detail here. This factor U does, for example, allow for the fact that the physical space and the space of experience are not identical (see Bertrand Russel 1914 and 1926, page 121). However, with the methods developed by C. G. Jung and his school, a more intensive step-by-step approach to a more objective grasp of this deceptive and relating factors U has been reached than has been the case ever before. Among other things, this work intends to take a preliminary inventory, which makes the sphere of experiences and some correlations between geological theories accessible to more exact scrutiny for history and psychology of science.

If one undertakes an examination such as the one we do here, one has to be aware that the examination of prevailing images of patterns of thought, etc., does not mean that one becomes automatically free of them. One is still subject to them, just as an examination of the composition of the air does not mean that one no longer has to breathe. Hence, it will hardly be correct to make a differentiation between the "closed systems of theories, on the one hand, and open patterns of thought on the other hand". There rarely will be "closed and open archetypic models", but more or less only dependency, subordination to these basic life forms, and the

degree of freedom therefrom is most of all a function of how much of it can be brought up into the conscious. If for instance, we proclaim out own thinking a product of open concepts and that of our idealized opponent a closed system of theories, this would only mean that perhaps we have become even more dependent on the concepts and, as some sort of self-protection, have projected our own shadow on our opponent.

Perhaps to differentiate and therewith attempt to set up a system which best corresponds to the observed natural phenomena is the most important method of scientific research. Whosoever thinks and differentiates most clearly can come up with the clearest system. Clear thinking also depends on the degree of freedom from binding patterns of thought. Therefore, scientific theories are also dependent on history, just as culture is in general. Hence, our scientific knowledge and our Weltbild can correspond to the height of the time, or it can be left in the unconquered bonds of general or personal historical development. This historical relativity has been expressed by Paul Niggli (1938, page 16) in the following clear wording, which also contains the basic idea of the epigraph prefacing this work:

"Because it is not basically the possession of scientific truths, but the successful search for deep insight that brings happiness. We are glad that, whatever the esthetic satisfaction is from temporary synthesis, 'there are no eternal theories in science' - that through our work, the reality of yesterday and the reality of tomorrow is a different reality than the one of today, and as Woelfflin puts it 'what seems to be alive today, won't be quite so tomorrow'. After all, in the stream of comprehension which steadily renews itself the genuine relationships, which we have recognized as such, will remain as partial solutions. The knowledge gained on a situation and the clarification of ideas are the bases of all creative thinking which discovers further paths of thought necessary to comprehension. The scholar feels that he is a link in the chain, he submits to the facts, to improvement, to clear conception, and deeper insight. For years Albert Heim did not accept the idea of Alpine nappe-structure only to become one of its distinguished interpreters after he had been overwhelmed by the abundance of new data.

"Science, which tries to grasp the contents of the world from an abstract point of view, has recognized the danger which hangs on words and the play of words, because it struggles with concepts which it has itself created and tries over and over again to discover their meaning and the area of their application, their significance and their history. In this way, it is also realized that it is chiefly the antiquation of concepts which bars so many from the sense and meaning of the progress in scientific work."

EXAMPLES OF DEPOSITS AND PETROGRAPHIC GROUPS

(for which epigenetic as well as syngenetic formation has been suggested.)

As a result of a study of the genesis of spilites, the genesis of ores and other genetic questions (which are partially covered in the bibliography under the author's name), the impression has been gained gradually that a deeper and simpler question hides behind all these partial questions - this is the question on the time relationship between geological bodies and their components, in other words the question of synchronicity or syngenesis and epichronicity or epigenesis, and the question of the space relationship, i. e., the problem of "allothigenesis and autigenesis".

This polarity of the genetic interpretations seems to be a pair of geological concepts. Other concepts appear as well which we can deal with only very shortly here, and the far-reaching analogy with that referred to in Jung's theories on psychology as archetypes tempted us to try to search for and demarcate the concepts or archetypes which are active in the development of the geological sciences. Among other things this shows that to some extent exactly the same concepts can be found in other sciences and beyond that in religion, esthetics and ethics as well. One easily assumes, and this could even now be confirmed with great certainty, that we are often subject to these patterns in our research, namely as soon as we start to interpret. The results of these comparisons were published elsewhere.

In the above-mentioned genetic analyses and the attempt which grew out of them, i. e., "to take an interest in one's ownself, and in the methods and ways of thinking" two surprising results and relationships became evident. For one, the polarity of interpretation seems to repeat itself over and over in most different areas and at the most different occasions, but also at most different times in the history of geological science and at the most different locations, and furthermore, without that the parties involved know about this coincidence. The inclination to a certain theory, a concept, also seems to be a characteristic of the researcher's personality, of the historical period and of the culture of the country involved.

Furthermore, some discrepances and differences, which to date have been in the foreground, appeared in a different light and lost in importance, for instance, the dispute on the genesis of granite. Therefore it may be hoped that a clarification of the nature of the syngenesis and epigenesis problem and also questions on allothigenic or autigenic origin may be stimulating for the development of petrographic and ore-genetic theories.

In the following we shall try to present in short summaries, partially including the author's interpretation, a cross-section of some major problems in ore and rock genesis. There could, of course, be listed many more examples which would just as well reflect the polarity of concepts or patterns related to syngenesis-epigenesis. For reasons of space we have restricted ourselves to only a few examples, and only occasionally can we examine individual criteria.

In spite of Planck, Einstein, Pauli, Jung, Portmann and many others, there are still men of science who call unscientific an interest in the method, the psychology of intuition and even the philosophy of natural sciences. In order to take some elements of scepticism away from these heirs of the second half of the 19th century, a comprehensive listing of literature will be included, in the hope that the reader will convince himself that many men have searched intensively and in as unprejudiced a way as possible for clean unambiguous criteria. Only because of and following many years of searching into the different branches of geological research, have these correlations which lie beyond customary methods of research been discovered and subjected here to a preliminary examination.

A. Sedimentary Rocks and Ore Deposits in them

a. "Kupferschiefer"

("red-bed copper-type deposits")

Copper deposits of the red-bed copper type are quite frequent and have been given a syngenetic as well as an epigenetic explanation. Groddeck (1885, as quoted by Pošepný 1893, 1895 and 1902, page 125) and others before him interpreted their origin, under all circumstances, as syngenetic. Pošepný reproached Groddeck, claiming that he was dogmatic (page 126) and offered criteria for epigenesis. This dispute is still carried on today. Examples are the enormous red-bed copper-type deposits in the Nonesuch-shale area of Michigan, which is superimposed on spilitic portions of the Keweenaw lava (Amstutz 1950a, 1956a, 1957b, 1957e, 1958b and 1958e; White and Wright 1954, and Rand 1956). According to the opinion of the epigeneticists, a subsequent infiltration from hydrothermal invisible fissures has taken place. As the author has recently shown, probably too many criteria exist which speak for syngenetic-hydrothermal origin, i. e., for exhalative-sedimentary genesis subsequent to the extrusive action which brought up the Keweenaw spilites, simply as the continued escape of the volatile constituents of the basaltic magma.

Finch (1933) has reviewed the copper deposits in the sediments of the western states of the U. S. A. in the volume on the deposits of the western states which is important also in other respects in relation to the genesis of ores.

Essentially, three variants can be discerned for syngenetic explanation attempts in relation to the genesis of the red-bed copper-type deposits: 1) the explanation of mineral content by introduction from continental rivers, among other things through the comparison of copper content in all-red-bed copper deposits with the copper content of present day surface-waters (Messer 1955 and others); 2) by arid concentration (various authors), and 3) by hot springs of the basic to intermediate vulcanism as suppliers of the ore (Huth, 1955, Schüller, 1958, and the author in various papers, and many others). Schüller has recently verified this opinion with exact criteria, but points out that the superimposed dolomite has been mineralized by epigenetically-mobilized solutions, which may also apply to the Permocarboniferous of eastern Switzerland and the superimposed Triassic dolomites examined by the author.

In this connection some more recent works may be quoted which attract attention through their conformity in experimental and observed phenomena. Rosenthal (1956) reported on experiments for the synthesis of marcasite, pyrite and magnetic pyrites from aqueous solutions at room temperature. Geis (1958) claimed for the Norwegian pyrite deposits (which the author, 1958e, independently has classified as exhalative-spilitic) a volcanic-exhalative syngenetic origin. Oftedahl (1958) reviewed the possibilities of exhalative-sedimentary ore formation, whereby however the perhaps not unimportant fact was ignored that exhalative-sedimentary and other syngenetic ore geneses have been expounded for over 200 years – sometimes more, sometimes less distinctly. An important bridge between observations in deposits themselves and experimentation has been supplied by the extensive review of Batholomé (1958) "On the paragenesis of copper ores".

It is noteworthy that transitions exist between the Kupferschiefer-type and the Colorado Plateau uranium types, especially in regard to a genetic standpoint. Such a transition-deposit in Nova Scotia was described by Brummer (1958). It was found that the present position of the ore should be interpreted largely as a secondary concentration from originally-syngenetic deposits. As in many cases, probably for instance very often on the Colorado Plateau, a superimposition of later epigenetic-supergene processes took place over primarily syngenetic-supergene or syngenetic-hypogene deposits. Gruner (1956) probably has described these processes most carefully, and thereby has also worked out useful guide lines for practical exploration work. The abundant and valuable older literature on deposits of the copper-slate type has been summarized by Schneiderhöhn (1955) and others.

b. Uranium Deposits of the Colorado Plateau Type

There is scarcely a type of ore deposits in the U. S. A. which has been more discussed recently that the uranium mineralizations in the sediments of the Colorado Plateau. When we speak of these deposits geologists realize the polarity or even the "four-foldness" of genetic theories more clearly than they realize this factor in relation to any other group of deposits. Here also, genesis is consciously brought into relationship with the method of exploration by most geologists.

Where Kerr (1956, 1957 and 1958) and his school defend an epigenetic idea, we find the same criteria for epigenesis expressed for other deposits, especially for the Kupferschiefer type. Further, Bain has in 1957 briefly summarized the main criteria for his hypothesis which he covered in his various papers. It is a complex hypothesis just like that proposed by Gruner, (1956). It originally supposes syngenetic origin for the uranium minerals which however today essentially occur in epigenetic-supergene rearrangement. In concluding he writes: "Considered from all points of view the evidence bearing upon emplacement of the uranium indicates that the Plateau ores owe their present position to solutions that were mildly hydrothermal but not hypogene" (page 195).

While for these Plateau deposits more papers rather prefer epigenetic-hydrothermal origin, the Kolm deposits in Sweden have almost exclusively been interpreted as syngenetic. Here too as stressed previously (1958a), sedimentary petrography will play an important part, as soon as more exact microscopic and stratigraphic studies are available. Similarly in this case the presence of fracture systems leads directly to the assumption of epigenetic mineralizations, and one forgets that the same type and number of "channel ways" exists usually outside the deposits as well, i. e., these per se do not represent a genetic criterion and that on the other hand fracturing can also reach up to the surface and consequently makes it possible that mineralization, which may actually have been proven to have emerged along fissures from below, can rise and escape to the surface.

Many attempts have been made to clearly illustrate the facts and various types of interpretations. The most comprehensive study of this type is Heinrich's book (1958) Mineralogy and Geology of Radioactive Raw Materials. It might have been preferable if Heinrich would have taken into consideration the present uncertainty of genetic interpretation. Instead of presenting his own opinion as one of the currently prevailing interpretations, he has chosen the somewhat dogmatic-appearing alternative, to use his epigenetic concept as the basis for the arrangement of his book. He describes the Colorado Plateau deposits under the title "Epigenetic stratiform deposits in sedimentary rocks". It can be noted again and again that in epigenetic interpretations it is assumed that minerals (the area of stability of which presumably is covered within the pressure-temperature (P-T) area of "hydrothermal" solutions) have been formed a priori and automatically out of incoming solutions.

To this effect Lange (1956, page 5) for instance tried to show that Ramdohr (1954 to 1955) has contradicted himself when he dismissed epigenetic formations because of the lack of gradients, i. e., so-called "differences with depths" and a lack of supply channels, but then points out that higher T's and P's do not only come about through migrating hydrothermal solutions after all. This is a perfect illustrative example of the fact that certain physicochemical conditions cannot be reserved for one and only one geological process.

On the other hand it is going too far if demonstrations of proof are based on a comparison between natural gas and petroleum on one hand and magmatic ore solutions on the other hand (Lange, 1956, page 7). Such comparisons slip in, especially with the effort to illustrate lectures. However, they are apples of paradise because they lead one into something that was not originally intended. The validity of this comparison is very limited. Apart from the fact that its chemical qualities alone are of a quite different nature, petroleum can hardly be considered as something coming up from "unknown" depths. Petroleum is something that was originally formed syngenetically and then may or may not have migrated (see section A). If a migration of petroleum takes place, then this corresponds to a secondary change of a primarily syngenetic nature, and that such migrations can take place in ground-water regions is hardly argued by any syngeneticist.

Just as the existence of fracture systems does not allow a priori the assumption that a migration of petroleum has taken place (especially in those cases where no evidence is indicated) neither does the existence of porosity allow for such an a priori assumption. Even less can we conclude from the presence of porosity directly on a hypogene introduction of ore matter. In other words, the presence of porosity is a criterion that can be interpreted in different ways. It makes migration possible, but does not prove it.

In addition, a perusal of those studies that speak of "highly-porous units" and rely on them as "convincing field evidence for epigenetic origin" showed that almost without exception all measurements on quantity and proofs are missing for the presumption that those strata are actually porous, or at least more porous than the surrounding rocks. Coarser grain is

often offered as proof for a higher porosity, yet porosity is much more dependent on the nature of the cement between the grains and the number and size of the pores in such cement, these factors being frequently difficult to observe even under the microscope.

As a final example of frequent "constriction of thought" which traps us if a dogmatic starting point is assumed, we should like to mention the precipitating properties of the organic components of rocks. Very often these are cited as epigenetic criteria for ore formation. How much more active, however, are these organic substances during sedimentation and diagenesis, especially in comparison with the final product – carbon in the form of graphite. Also, it is possible in a syngenetic-sedimentary environment – as for instance becomes obvious from observations and experiments with recent sedimentation milieus – that acids and putrefactive materials, etc. exist, which will withdraw or fall apart and dissolve in the water before or during diagenesis, but can play a very important catalytic role in the syngenetic precipitation of matter. Thereby, the syngenetic deposits without or with only a few remnants of organic substances are readily explained, whereas one has to turn to sundry hypotheses for an epigenetic explanation.

As with most of the deposits covered herein, we cannot dwell on the details of syngenetic or epigenetic criteria of the Colorado Plateau deposits in this study. Nevertheless, it seems to be an established fact that slowly in quality as well as in quantity syngenetic criteria are taking over. Ramdohr has, for example, some time ago found raspberry-like groups of bacterial structures in samples of the Mi-Vida mine. Such criteria, which in their turn stem from a precise method of research involving ore microscopy and sedimentary-petrography, differ from merely regional-tectonic "considerations" and "evidences", and are slowly gaining ground. The MS thesis by Chico (1959) gives a review of the criteria used by syngeneticists and epigeneticists. Among other things it is pointed out therein that the syngenetic mode of thinking is not at all new, but only a factor which was being pushed aside or neglected by many schools of thought. For example in 1935 a Princeton student wrote an excellent study concerned with the vanadium and uranium deposits in the Plateau, which contains the following sentences, unfortunately hardly noticed in the last 20 years: on pages 90, 91 and 92, Freemann stated —

"The main point in favor of a syngenetic origin of the ore deposits is their apparent persistency of occurrence at approximately the same stratigraphic horizon over widespread areas... There is the question of a favorable bed in which material, concentrated by meteoric waters, could be deposited to form the present ore-bodies, as is proposed by the 'epigenetic school'. It has already been emphasized by this writer that there is no reason to believe that one horizon in the La Plasa, or one massive layer in the Morrison is more favorable than any other. For the most part, the sandstones of both these formations are remarkably well sorted and always show an evenness of grain. Broadly speaking, one cannot lay his finger on any particular sandstone bed of either formation and say that it is more porous than any other.

"Many authorities claim that the organic remains in the Carnotite bed of the Morrison made this particular part of the formation a favorable locus for redeposition of the metals. It is significant that equally as much organic material is to be found in sandstone layers above the Carnotite horizon.

"Furthermore, there are no impervious beds in the close vicinity of the ore horizon anywhere which could possibly dam circulating mineralizing waters. True, there occur a number of shaly layers in the sandstones of the Morrison but these are everywhere local and not continuous for any great extent.

"Regarding the question of structure as an agent in the concentration of disseminated vanadium and uranium by meteroric waters, it has already been emphasized that nowhere do fault planes show any sign of mineralization."

c. Pyrite-uranium and Pyrite-uranium-gold Deposits of the Blind River and Witwatersrand Types

Here too we can see the dispute on epigenesis and syngenesis sway to fro. Again it is challenging to leaf back through history and to discover that as early as in 1839 Sawyer, and again in 1893 Pošepný presumed syngenetic-detrital origin, as Liebenberg (1956) and Ramdohr (1955 and 1958) do presently, while epigeneticists like Davidson (1957) energetically fight syngenetic ideas.

A short visit in the Blind River mines, the study of samples from Blind River and Witwatersrand, and the study of the literature appear to point distinctly towards syngenetic formation, and we should like to agree with Pošepný (1893 to 1902, page 163) when he stated "I suppose the gold to have been deposited at the same time as the detritus".

As was already stressed elsewhere herein, it is advisable for the student of mineral deposits to consider as well sedimentary-petrographic and geochemical criteria. Surely Lyell did not interpret the actuality principle so rigidly that, if he were still alive today, he would not realize that presumably the Precambrian atmosphere may have been short of or without oxygen for some time, a possibility which is categorically denied by Davidson in order not to offend the actuality principle. Quite likely Lyell would

have nodded in agreement had he heard Russel's Presidential Address of 1957 in Atlantic City (1958, page 5):

"The stratigrapher and sedimentologist are most concerned with the consequences of erosion. In deciphering the record, however, they should" and here one can probably add today with special emphasis – also the ore geneticists– "bear in mind the probability that the earth's landscapes, together with all erosional and depositional processes, have undergone at least four great changes which were related to the vegetational cover of the land, and hence to the soil development... The naked earth which existed prior to the middle Paleozoic certainly was without soils in the modern sense... The Cenozoic... completed the change to the earth's surface we know today. Never before has the earth been armed so well against processes of weathering and erosion. Effects of this armoring must exist in sedimentary deposits to a degree which makes it a bit hazardous to press too far any interpretation of the remote past on the basis of the present." (Accentuation by the present author.)

In order to add just one example of sedimentary petrology which is simply also "common sense" as well, let us mention the contention of the epigeneticists that round pyrite grains are replaced detrital quartz grains. Yet one does not find any transitional stages towards partially-replaced grains. Whenever we defend epigenetic theories we should not forget that one of the indispensable criteria is always the existence, the finding and the proof of gradients. In other words, if metamorphism is assumed from stage A over transition stages B, C and D into a final stage E, we should be able to discover the intermediate stages B, C and D or have plausible explanations why these cannot be found or no longer exist. It is hardly possible to overemphasize this requirement. Transitions, gradients and zones are in most cases a sine qua non for epigenesis, but hardly ever or never can they be used as the sole proof for epigenesis.

The above applies to the telemagmatic-diffusionistic interpretation of the so-called "impregnation deposits" where we are often missing the stages A, B and C, because of the absence of metasomatic ("replacement") criteria and of introduction channels, as well as to the so-called granitization processes, where "mineralization" is often said to take place without roots and gradients to the source. Where these gradients are missing, such as at the Witwatersrand and Blind River deposits, what Wiebols has recently written about Davidson's criticism of Ramdohr's study is applicable: "The 'Deus ex Machina' is clearly on the other foot" (1958, page 759).

d. Vanadium in Layered Sediments (Mina Ragra type)

The vanadium deposit of Mina Ragra in Peru, which the author had the occasion to visit in 1956, offers a didactically excellent example. For several decades Mina Ragra was the main vanadium supplier (previously more than 50 percent of the world production). This deposit, situated approximately 4,800 meters above sea level, consists of a concordant lense of sulfides, symmetrically imbedded in sediments ranging from a coal to a sandy-shale type. The old theory closely adhered to the principle that "where there is ore, something has intruded and was changed metasomatically" or "ore deposits are normally replacements". Hence, not only the mining engineer spoke of a vein (which is actually usually intended to mean only geometrically and not genetically) but the geologist did so likewise. There are even some studies which attempt to establish a genetic connection between dykes of rhyodacite which cut vertically through the ore deposit and the mineralization.

On the basis of the old epigenetic theory some exploration has been carried out near numerous other "dacite-dykes". Yet, considering the sedimentary-syngenetic concept this does not make any sense; one should rather examine the typical stratigraphic horizon in order to determine if lenses with similar conditions of deposition and perhaps similar ore-contents appear, and this is in fact the case.

However, here too, it should again be pointed out, that the syngenetic concept is by no means, as has been claimed, an "accomplishment of the 20th century", but has prevailed for a long time alongside the epigenetic concept. Thus, for instance, Phillips (1918) reported on the possibility of a syngenetic enrichment of vanadium through echinoderms. The Mina Ragra example is only one among a great number which could be quoted in order to show to what extent practical exploration depends upon sound genetic concept in order to assure permanent success.

e. "Kies" and Sulfur Deposits of the Meggen, the Nairne (Australia) and the Kuroko Ore Types (Japan and Formosa)

We find that mainly syngenetic explanations have been applied to the Meggen-type deposits in Germany, Nairne in Australia, the black sandy pyrite shales in Formosa and Japan, and others. Most recently Meggen has again been examined by Seifert, Nickel and Bruckmann (1952) and by Nickel (1956), and has been reinterpreted syngenetically; to some extent this had been the case previously. In 1950, Ridgway claimed that Nairne is epigenetic-metasomatic. Knight in 1957, and recently Skinner (1958) who offered even more data as proof, claimed it is syngenetic.

Ho (1953) described sulphur, chalcopyrite and pyrite deposits in the black shales of Formosa, where volcanic activity can be noted. The

same is obviously true for the important Japanese Kuroko ores as well as for the Japanese and central Italian sulphur deposits. Among other factors, one of the main tasks in ore genesis is to explore the conditions of deposition in sedimentary environments, i. e., to concentrate even more on the petrography of sediments and not solely on the petrography of magmatic rocks.

In this connection, we have already seen, and this will probably become more and more obvious, that the volcanic-exhalative portion of the material dissolved in sea water is quite substantial. This, among other things, becomes evident in the studies of Bernauer (1934 and 1939), Kraume, Ramdohr et al. (1955), Zies (1929), Allen and Zies (1923), Cissarz (e. g., 1956), Taupitz (1954 and 1955) and Stanton (1958). According to examinations by the author (1958a, 1952b, 1954c, 1956a, 1958b and 1958e) it also appears probable that various deposits that heretofore had partly been explained as being epigenetic will rather have to be explained by syntenetically supplied exhalations. Ross (1947) believed that volcanic emanations are able to transport metallic elements, but bypassed an examination of the quantities involved and consequently also bypassed the practical consequences. The same can be said of Bateman's textbook, which even though it lists numerous examples of exhalative sulfide ore-minerals formations, denies the consequence (in another connection, namely the review of Niggli's and Schneiderhöhn's classification of ore deposits). Only today are the extensive studies of Paul Niggli (1912, 1929) again given some attention, because in several respects he was ahead of his time.

Many things still have to be clarified with reference to the extent of the formation of deposits related to submarine, primarily geosynclinal volcanism. On the basis of recent studies it has, for example, just become apparent that the mercury deposit of Idrija is connected with a Triassic geosynclinal magmatism, and thus is syngenetic (Cissarz, 1956). This interpretation makes it seem possible, if not probable, that the very similar Peruvian deposit of Huancavelica and others were formed during extrusions in geosynclines.

Typical examples of euxinic milieus are always the coal-deposits, where often layers of pyrite and pyrite concretions and "impregnations" and other sulfide forms are found in large quantities. Bacteria living in the oozes can build up sulfides in a manner similar to the ways carbonate shells are produced by other marine organisms. Such sulfide-forming microorganisms were recently very clearly depicted and described by Love (1958). Euxinic conditions exist also in the present seas, and are probably being particularly well-furbished near submarine exhalations.

The barite content of the Meggen deposits, as well as that of that of other sediments, was interpreted in 1936 by Engelhardt as supergene only. That very often transitions to a volcanic-exhalative origin can be proven was, among other factors, pointed out by Taupitz (1954 and 1955), and the author (1958g). In section g, it is mentioned that the largest barite deposits, i. e., those in the Dolomites and in Missouri limestone, have often been interpreted as epigenetic metasomatic products, but also in this connection very early in the game syngenetic ideas were presented.

It should also be pointed out here that there exists early experimental work on barite genesis. Fischer (1916) was successful in separating $BaSO_4$ colloidally and in successive layers. Sometimes we erroneously presume that experimental geology is a modern trend. Yet for quite some time many geologists, those of Paulis' "thinking type" as well as those of his "feeling type" (1952, page 161) have used experimentation as an important tool in approaching new cognizance. One has only to think of Goethe's and Liesegang's experiments (Carl and Amstutz, 1958j), and of Hall's experiments prior to 1805 as proof of the theories of his friend Lyell. Here too it is worthwhile to study earlier works, if we do not want to take previously established facts as new discoveries.

f. The Deposit Groups of the Rammelsberg, Rhodesia and Katanga, Broken Hill, West Tasmania, Mount Isa, Bathurst Maubach-Mechernich, Ducktown Types, etc. with Remarks on Franklin, New Jersey

All these deposits have been extensively covered in the literature, which shows again the same amazing polarity of epigenesis and syngenesis, and often, even to the smallest details without knowledge of other areas, the same criteria for and against the advocated and/or assailed concepts are offered.

The clearest illustration of the lively history of these theories has probably been given for the Rammelsberg deposit (Kraume, Ramdohr et al. 1955).

The copper deposits of Northern Rhodesia and Katanga have raised the same dispute, where Brummer (1955) represented the syngenetic side and Davidson (1931, 1954 and 1955), Garlick (1955), and earlier also Bateman (1930) represented the epigenetic point of view. Bateman and Jensen (1956) showed some time ago that sulphur isotope measurements did not yet allow a final conclusion on one side or the other. It was forgotten, though, that a volcanic exhalative origin probably may also produce $S^{32/34}$ ratios coming under the hydrothermal category, because with strong exhalations the fractionation in sea-water is hardly strong enough to com-

pletely alter the conditions. In the quoted study, hydrothermal origin was again considered as being equivalent to epigenetic, a train of thought which should be carefully avoided. The author (1959) has recently pointed out the relationships between the sedimentary and the exhalative field for $S^{32/34}$ conditions.

The history of viewpoints on the Australian deposits of similar structure and ore composition as those mentioned above, has been described in many studies on the structure and geology of the Australian deposits edited by Edwards (1953).

Our thesis that at many locations and by various authors, and with reference to different types of deposits, again and again (and thousands of different times), the same criteria and discussions appear and come up again and again is supported indirectly by many of the cited papers. It is most noteworthy that Knight (1957), apparently completely oblivious of the fact that the same problems were weighed and discussed a century ago in extensive painstaking research, simply conceived his "source bed concept". One should be rather grateful to Knight that he so clearly corroborated the persistence of "patterns of thinking" or of hypotheses. We shall discuss this in greater detail in the analysis of archetypic roots of geological ideas.

With reference to Knight's work, it might be well to point out here that John Woodward (see Winchell in Pošepný, 1893 to 1902, page 192) as early as 1723 and then in the 18th century, most importantly, Sandberger have improved and defended the idea of the lateral secretion formation of mineral veins. The criteria listed at that time are even better differentiated than many of those published today. A short, not very objective or complete presentation of some important historical developments in the field of ore genesis has been offered in English by Crook (1933). Somewhat more complete is the survey by Adams (1938), and the bibliography of Fenton and Fenton (1952).

The Maubach-Mechernich deposit was described by Behrend (1950) and the Tellig deposit recently by Cup (1955). Both experienced a similar change in interpretation as in the case of the Rammelsberg. The stratigraphy of Mascot-Jefferson City was recently extensively described by Bridge and Rogers (1956). The author has a short time ago pointed out the probability of a syngenetic-sedimentary explanation of the Tennessee deposits (1958b), and as of late the mining geologist of Jefferson City has supported this with detailed criteria (Kendal, 1958) independently of the author.

As practically all these deposits have gone through light to major metamorphism, it might be a good idea to dwell somewhat on the consequences of metamorphism in these deposits, because even in the evaluation of these consequences a definite polarity of opinions becomes apparent. Whereas Backlund (1941), Wegmann (1956) and others, and now even Schneiderhöhn (1952 and 1953) assume a mobilization during deep burial and heating of sediments; Ramdohr (1953), Borchert (1954 and 1955), and others showed that much is to be said against such an assumption, and that roasting off or a remobilization can probably only occur during palingenetic fusion (Borchert and Tröger, 1950). These contemplations border on the granite problem and shall be discussed more thoroughly there.

Nevertheless, in connection with the cited studies of Ramdohr, Borchert, Backlund and Schneiderhöhn (to name only a few), we want to show here what we will bring out later as a major characteristic in the concluding remarks, namely, i. e., if one tries to approach both theories unprejudiced, one cannot help noting that the syngenetic explanation is much more concrete, simpler and less contrived and hypothetical. The claim by many epigeneticists that "field evidence" justifies their concept is only of a purely rhetorical nature, because it is evident that both sides, the epigenetic as well as the syngenetic, make observations, and that both are to the same extent subject to the danger of not clearly differentiating their observations from their interpretations and of reading a finding in Nature in the terms of a preconceived interpretation.

The route from observation or inventory-taking to explanation or interpretation for a geological phenomenon leads through various steps, and if we already "see" from the beginning how something has come about, then this is very often an indication that we have gone into the field with a preconceived idea. The most important of these steps are probably the following ones:

1) Stock-taking per se, measurements, drawings and other observations – actual analysis.

2) The logical synthesis of these data, e. g., of groups of the same type, diagrams, etc., which do not yet represent a onesided interpretation (partially even rather analysis).

3) The continuation of the synthesis by comparison with familiar circumstances following our memory and the world around us (literature, other outcrops, samples, analyses, etc., and – which is especially important – a comparison with experiments in physical chemistry); 2) and 3) are the beginning of an interpretation.

4) Main interpretation: the individual pieces in the previous steps are brought together in one overall picture. This, provided it does not involve something already well-known, originates in us. It is our creative act, a part of ourselves, i. e., the principle which we see in natural phenomena. Therefore it is subject to

the change with history and will, when it has reached the light of the time remain valid for some time only, and then be overridden. (Details on the character and the historical nature of our ideas or theories have been published in another paper).

Great principles are generally simpler than the data and ideas which existed before. A good example is the periodic system and the bedlam of individual properties of the elements which the student had to learn by heart prior to it. The same is true for the field of mineralogy before the crystallographic systems and classes were discovered.

Bertrand Russell (1946) has expressed this very simply is his foreword to Clifford's The Common Sense of the Exact Sciences:

"The other thing that must be done"... in teaching and in research... "is to discover the point of view from which a subject is most easily surveyed. A wood in which the trees are planted in rows looks regular when viewed along a row from one end of it, but may appear completely higgledy-piggledy when viewed on a slant. The same sort of thing is true of a mathematical subject..." (page ix).

Those who concerning this and other groups of deposits, want to form an opinion on who is seeing "order in the forest" and which of these concepts relies on fewer assumptions should read the epigenetic and syngenetic papers and comparisons, among others Borchert's "critical remarks concerning two new studies on Outukumpu". Of course, if possible it should not be neglected to study first of all the deposit itself, including typical samples and polished specimens.

It is quite obvious and was hardly ever doubted in any study that deposits like Cerro de Pasco, Casapalca, Morococha, Grund, Butte and many others are totally or to a large extent formed epigenetically. However, if exaggerations, i. e., the thinking in terms of contrasts and extremes appeals to so many of us, we probably have to retreat a step and ask ourselves, why this is so. This will only be started herein and continued in another publication.

Because we have already touched on metamorphic processes, we shall discuss one additional deposit, i. e., the Franklin deposit in New Jersey, which after the recent discovery of a similar deposit in Russia is no longer the only one of this type. It too has already been explained in many different ways, and here too, the ideas seem mainly to fall into two groups. They were recently briefly summarized by Metsger et. al. (1958). On the one hand one seems to be inclined to presume that this is a highly metamorphic "impregnation deposit" which released readily-volatile sulphur during the metamorphism, as stated by the author as a possibility for comparison in a small study on the roasting of zinc ores (1957f). This, of course, only postpones the genetic problem without actually solving it. The other possibility is a later introduction of zinc sulfide or oxide. But in general there is still a tendency to hold back final conclusions.

g. The Mississippi Valley-Bleiberg-Silesia type

Today the genesis of the Mississippi Valley deposits are again discussed, due to the fact that a few years ago intensive explorations of continuations in the lead belt and the tri-state district have set in. But perhaps this has also been caused by the fact that, try as one may, observations on the genesis in these deposits could not be made to correspond with existing theories, and therefore attempts "to get gradually closer to the truth by doubting all prevailing theories" were made.[5]

The Mississippi Valley deposits have received their name from the fact that, not only from a stratigraphic, but also from a structural viewpoint, similar deposits are scattered over a district situated almost exclusively in the drainage area of the Mississippi River.

This area supplies nearly two-thirds of the total lead and zinc production of the entire United States. Somewhat more than a third of the total production of zinc originates from the southern tri-state area and from similar deposits in Tennessee (Mascot-Jefferson City, etc.), and somewhat more than a third of the total lead production comes from the lead belt. The southern tri-state field covers the border areas of Missouri, Oklahoma, Kansas and Arkansas and should, therefore, actually be referred to as the "Four-State" area. The tri-state area and Tennessee, and the lead belt are, incidentally, also the largest zinc and lead suppliers, respectively, of the world.

Genetically, it is quite important to realize that the main deposits extend from Cambrian dolomite in the lead belt all the way to the Lower Carboniferous limestone of the tri-state area, which means they extend stratigraphically over

[5]It is a pleasant duty for me to thank the chief geologists and mine managers of the Eagle Picher Co. in the tri-state area, the St. Joseph Lead Co. in the lead belt and the National Lead Co. in Fredericktown at the genetically important southern end of the lead belt, for hospitality which the author had occasion to experience again and again in numerous discussions and visits to the mines.

a great period of time. In other words, the vertical extension over the whole Paleozoic as well as the tremendous areal distribution, have to be taken into account. Smaller and larger deposits of the Mississippi Valley type extend from Canada, to Wisconsin through Illinois, Tennessee, Kentucky, Arkansas, Missouri, Oklahoma, Kansas and Texas.

In the Missouri area alone one can find over 300 lead, zinc, lead-zinc-barite or barite deposits which were examined and worked earlier or are still being mined at the present time. The host rock varies markedly and irregularly. Lithologically the mineralization is bound exclusively neither to sandstone, limestone, dolomite, chert, argillaceous slate nor to a specific change of facies. The largest amount of lead ore is, however found in the dolomites, whereas zinc ore is predominant in partly dolomitic and cherty limestones. However, one should realize that dolomites and limestones prevail in the whole area by far. The Lower Cambrian sandstones and conglomerates rarely warrant mining, whereas numerous shaly beds in the dolomites and limestones exhibit in places a high content of lead.

The study of the fabric shows the sulfides almost exclusively as texture-homologous grains, which correspond in shape, size and arrangement to the dolomite, limestone, chert, shale, etc., not considering borderline cases which are often genetically ambiguous.

It would be quite a stimulating task to point out the details of grain fabrics, for the time being even without any genetic interpretation, leaving this up to each individual investigator. As this is not possible here due to space limitations, we have to refer to a study about to be completed which points out and interprets these details systematically. We give a summarized quotation of the results:

From the petrofabric orientation of the individual ore grains and groups, we can clearly assume a syngenetic sedimentation and syndiagentic growth of crystals. The pre- and syndiagenetic growth of crystals cannot be confused with epigenetic phases of solution and resolidification or even less with mimetric metasomatisms. Another reason why this is impossible is the fact that geopetal, i.e., clearly syngenetically-sedimentary textures prevail, comparable to those described in great detail by Shrock in his book Sequence in Layered Rocks.

Thus for instance, an idioblastic sulfide growth has taken place during sedimentation or during diagenesis. In that case the following shale layers settle over the sulfide porphyroblasts just as over a pebble which was washed in. Sometimes these sulfide porphyroblasts form dendrites, e.g., chalcopyrite in Fredericktown, or stars, e.g., of lead sulfide in the National Mine. The numerous concentric concretionary geopetal gel-structures of galena, marcasite, chalcopyrite and linneite can likewise only be interpreted as syngenetic-sedimentary, especially in their correlation to the surrounding shales.

As mentioned above, we could point out innumerable fabric details, which all indicate that the main process of formation of the deposit could not be epigenetic metasomatism, but that the ore minerals are homologous in fabric and hence were present in the rock from the beginning. The reply of the extreme epigeneticists is, of course, that we are here dealing with mimetic metasomatism. The lack of epigenetic criteria proves that this objection is invalid. Especially, those gradual transitions are missing that are indispensable for epigenetic metasomatism.

One other factor, however, should also be stressed. Not only are the microscopic criteria for metasomatism missing, but also the macroscopic zonings and gradients which must be present to warrant an epigenetic interpretation. The differences in the concentration of substances and in the size of grains can be explained simply and without difficulties by a syngenetic process of distribution. And if, which is rarely the case, sometimes a vertical arrangement occurs in form of a small, short, so-called "vein" or a vertical impregnation, there is no reason to presume another genesis for sulfides than for calcite, dolomite or chert, which once in a while also appear vertically and nevertheless are by no means explained epigenetic-hypogene-hydrothermally.

Indeed, it is quite strange that we have a tendency to evaluate a sulfide fabric differently than a country rock fabric even when strictly from a geometric viewpoint, it is the same thing. This suggestive power is transferred from the sulfides even to the cherts and dolomite zones. When no sulfides are present, the dolomites and cherts are often interpreted syngenetically. As soon as sulfides are present one believes that the very same cherts and dolomite zones have to be explained epigenetically.

While the lead belt geologists in Missouri, and also many geologists of the tri-state areas of Oklahoma and of Wisconsin, no longer regard dolomitization as a process of epigenetic-hydrothermal metasomatism after the discovery of extensive coral reefs in the dolomites some years ago, other geologists in other areas still claim a totally epigenetic dolomitization, in spite of the precarious problem of space which is more obvious than in the problem of the magmatic formation of granite. Lange (1956) for example, claims thus in his review of Hlauscheck's studies of the French oilfield Parentis, referring to the papers of Behrend and Berg (1927) at least for the greater part of dolomites still a completely epigenetic metasomatic origin.

The syngenetic explanation removes these

contradictions, too. Through the discussion on syngenesis and epigenesis we have thus far only touched the time of the formation of mineral deposits, and we saw that a syngenetic origin — in the examples discussed — is more probable. The criteria quoted originate mostly in the Lead Belt. Similar structural analytic results are present in the tri-state area, in the fluorspar area of Illinois, the barite area of the Lead Belt and of Arkansas, in Wisconsin and other ore areas of the family of Mississippi Valley deposits. The "pitches and flats" in Wisconsin can, for example, be explained as late-diagenetic tears or as tectonic tears with local lateral-secretionary rearrangements of PbS, $CaCO_3$, SiO_2, (Mg, Ca) CO_3, etc. and the breccia in the tri-state do not only lack noteworthy traces of metasomatism, but show numerous mineralized syngenetic erosion zones and submarine erosion forms.

Before we will proceed to the discussion of the source of the ore matter, we want to erect a sign of warning: even though it seems to be established that syngenetic formation seems to come closest to doing justice as the main process observed in the studies of the Mississippi Valley type deposits, we should on the other hand not exaggerate this. In case that the introduction of matter should have taken place from below, it is to be assumed that part of the ore discharge has perhaps already moved to rocks that are metasomatically capable of reacting. However, then one should still be able to see this and also to find continuous vertical veins. But those, to date, have been observed only in the fluorite province of Illinois and nowhere else in the large extensive areas. In deposits which are connected with geosynclinal volcanic activity, it is often observed that exhalative – marine-sedimentary and also subvolcanic – hydrothermal-metasomatic ore formation takes place, as, for instance, Cissarz emphasizes in his "Discussion of the studies of Maucher 1957 and Petrascheck 1957". A telemagmatic soaking was, however, not mentioned anywhere.

Thus, we have already begun to discuss the question of the source of matter and we now want to contemplate where from these ore solutions could actually have originated. For this purpose we will delve into the theories developed by leading geologists. Up to now only three of the four existing possibilities AI, AII, BI, BII, have been advocated, i. e., AI, BI and BII.

The syngenetic explanation is so obvious that sometime earlier there was already a syngenetic school, represented by Professor Dake (1930). He, however, explained the supply of matter as of supergene origin from weathering products. The details of the fabric and the geochemical criteria, which will be discussed at a later time, were apparently not sufficiently demonstrated and discussed, because the epigenetic interpretation gained in strength again.

The main representatives of an epigenetic-supergene genesis were Bain, Van Hise, Adams, Winslow, Buehler and partially Buckley, whereas the epigenetic-hypogene genesis was represented by Tarr, Pirsson, Emmons, Graton, Bateman, Brown, Ohle and others. This last explanation was, so to speak, the only one to be recorded in European literature. Brown's "metallurgical theory" can merely be regarded as a variant of the last-mentioned theory.

By the supergene origin of lead-zinc-barite materials one meant weathering solutions and hardly ever did someone mention the actually-strange possibility of detrital sedimentation. The weathering solutions are partly accounted for as stemming from the sediments themselves, and partly as originating from the Precambrian basement.

The hypogene derivation of ore solutions, which for some decades has been elevated to an orthodox concept, and which has also established itself in European textbooks, introduces hydrothermal solutions telemagmatically in the Paleozoic sediments. If one stops to consider that an area as large as central Europe would thus have to be mineralized telemagmatically and then one still does not know the feeder veins, one becomes aware of an additional great difficulty in the attempt of an epigenetic-hypogene explanation.

It has to be stressed that nowadays most geologists of those ore companies who come in "daily contact" with the Mississippi Valley deposits, systematically dismiss a connection between the large and small fracture systems penetrating these deposits and the mineralization – apart from possible lateral secretions. Therewith they have broken with the traditional theory that fracture systems a priori serve as exclusively epigenetic channel ways. Very likely this theory had been based only on analogies with definitely hypogene-hydrothermal veins and not on observations and physicochemical criteria per se. This step towards the liberation from preconceived ideas should be warmly welcomed. Yet the adherence to the epigenetic concept, in spite of this, necessitated a new theory of ore source and thus probably triggered the publication of the "metallurgical diffusion theory" by Brown (1948).

Equally important as the geometrical criteria, even if not quite so unambiguous, are the geochemical data. First of all we find that the paragenesis appears to be quite "normally hydrothermal", due to the presence of Cu, Co, Ni, As, and Ca, though the Ag is missing and the distribution of the Cu, Co, and Ni is somewhat lopsided and limited almost exclusively to one particular area, namely the southern part of the Lead Belt. The fact that the Ag is missing fits in excellently with the theories of

those, who undertake the precipitation syngenetically and with the sediments, because, as is well-known, the Ag may be finely distributed, adsorbed by the clay minerals and thus separated from the lead.

A large number of papers exists on syngenetic origin of the "non-ferrous sulfide deposits" which, however, are not very well known in English-speaking countries. Many of the criteria pointed out therein apply for almost all Mississippi Valley deposits. We only want to mention here one particular genetic relationship which was recently pointed out by Huth (1956) in his review of the "Geology of the stoney marl beds, especially the lead sulfide beds in the gypsum-Keuper".

"Sedimentary-syngenetic non-ferrous sulfides are concentrated in the galena bed and in the other stone-marl-beds where the temporarily immigrated marine copper fauna found favorable living conditions in the mixed water between the saturated brine of the inner basin and the fresh-water coming in from the highlands." (page 17).

The appearance of dolomitization and the formation of chert in frequent association with ore is not unusual either, because Mg and Si are completely normal exhalative components. The dolomite and chert problem is discussed below.

Lead and sulfur isotope measurements, as well as studies of fluid and gas inclusions in single crystals, have been made in addition. Two groups have been at work on isotope measurements, obviously without knowledge of each other. One of them under the leadership of Professor Houtermans in Bern has developed the best methods from a physical standpoint, and with one exception, has eliminated all objections against the interpretation of the results. This one objection is that in the respective studies the possibility of fractionation during sedimentation, as for instance is caused by sulfur bacteria, has not been taken into consideration and furthermore the certainty of the geological origin of the samples has perhaps not always been paid the proper attention.

The second group has, upon prompting by the author (at least in the study of the Peruvian galenas), made its task, a careful inventory-taking of the isotopic composition of genetically unambiguously known deposits in order to provide a scale for an unequivocal basis of comparison. A number of lead sulfide samples has been collected from unambiguously hydrothermal veins from Peruvian deposits. The results of the measurements led to a simple column of values which now serves as a basis for comparisons (Kulp, Amstutz and Eckelmann, 1957). In the studies made by the Bern Institute of Physics, one analogy is perhaps striking – this is the one between the values of the exhalative-volcanic lead of Mount Vesuvius and the values of the Mississippi Valley deposits. This analogy is possibly an indication of a similar genesis. — The studies on inclusions have not shown any clear results.

In conclusion of our rather jotted-down discussion of the genesis of the Mississippi Valley deposits, we should like to introduce two main criteria for the exhalative nature of the larger part of these deposits – the presence of volcanic tuffs and the arrangement of the deposits alongside polygonal structures which have apparently experienced several rejuvenations, i. e., repeated movements, and might have again and again served as syngenetic channel ways.

We are again thereby confronted with what we have already mentioned briefly in the beginning – the systematic step-by-step analysis of the fabric, the mineral constituents and the geochemical circumstances does not lead us to a telemagmatic interpretation as offered in some textbooks, but to a simple sedimentary explanation, whereby presumably the sulfide content including the Mg and part of the Si has come from submarine-volcanic exhalations.

If one advocates a syngenetic-sedimentary origin for these deposits in a discussion with representatives of the epigenetic schools, one usually receives at once the reply "No, these deposits are hydrothermal, because the mineral paragenesis is hydrothermal". One can only answer this: "Yes, they may be hydrothermal, but the term hydrothermal is not to be confused with, or regarded as a synonym for epigenetic".

This has brought us up to an important point of our discussion of the genesis of mineral deposits. If one for instance glances through Bateman's textbook Economic Mineral Deposits, one finds that, apart from the Lahn-Dill iron ore, there is hardly an exhalative deposit mentioned. With Bateman as a matter of fact, partly even with Lindgren, many quietly assumed that hydrothermal solutions are always deposited obediently in the interior of the earth, and diffuse often for miles laterally into the enclosing rock, instead of, which would be much more natural, ascending for a mile or less to the surface of the earth and being exhalated. This tacit presumption is all the more surprising as Bateman points out observations of exhalatively-formed ores no less than five different times in his textbook and quotes from papers of Zies and Allen.

It can be assumed that many fractures, which so to speak serve as exhaust pipes for the volatile components, reach all the way to the surface of the earth and deliver a large portion of the material to the sea, where, if conditions are favorable, it will then be deposited.

Some years ago the sedimentary-homologous immense horizontal extent of the Mississippi Valley deposits has already caused some epigeneticists to think of an intermediate solution which assumes that the hydrothermal solutions almost reach the surface of the earth, i. e. ,the ground water, and were precipitated therefrom (Behre and Garrels, 1943). Here too, one encounters the difficulty that the syngenetic fabrics are not explained and, then again, it cannot be understood why the fractures and fissures which served as channels for the hydrothermal solutions should have ended, of all places, in the ground-water area, and why the precipitation of the entire metal contents should have taken place in the ground-water area.

These, however, are only additional obstacles in epigenetic interpretations. The most decisive criteria are those in the small scale and those of the regional extent cited above. Several attempts, such as those by Ohle and Perry to establish a connection between the degree of mineralization and porosity values, have had completely negative results.

Now the North American deposits of the Middle West are not the only ones of the Mississippi type, but quite a number of similar lead-zinc deposits belong in this category as well, such as for instance the Upper Silesian deposits which are the most important lead zinc deposits in all of Europe and also some North African deposits and many eastern Alpine lead-zinc mineralization, e. g. , Bleiberg and similar deposits in Sweden, France, South America, etc.

These Alpine and Silesian deposit groups have already been discussed more extensively than any others.

Friedrich (1937 and 1953), Clar (1953), Petrascheck and Petrascheck (1950), Colbertaldo et al. (1956) and others represent the epigenetic standpoint, while Buschendorf (1950), Hegemann (1949), Maucher (1957), Schneider (1953), Taupitz (1954) and others the syngenetic one, while Schneiderhöhn (1951, etc.) regarded the minerals as regeneration products and therefore his stand too should also be included with the epigeneticists. The genesis of the Wiesloch ore is as well reconsidered at this time, because it too shows partially a typically-homologous structure.

In England we find very similar conditions in the Paleozoic as in the Middle West of the U. S. A. But circumstances there seem to be much more simple in so far as we do not only find texturally homologous "disseminated deposits", but as well truly vein-shaped deposits. In addition, similar deposits exist in the Precambrian rocks as well and, which perhaps is most important of all, there are intrusive granites of the Lower, Middle and Upper Paleozoic. These might be held responsible for the syngenetic and epigenetic mineralization. Dunham's (1948 and 1952) papers offer good criteria for this correlation between syngenesis and epigenesis, even though Dunham claimed that the conforming, structurally homologous deposits are epigenetic.

The problem of ore genesis in all shield areas is still very much open. Just as it is being assumed that in nonorogenic areas a quieter differentiation of magma takes place (Geijer, 1922; Tilley, 1958, page 324), it probably can be also assumed that a more quiet, and particularly long-term development of ore solutions takes place, which are probably often the volatile constituents of a magmatic differentiation sequence. These would then have gradually risen to the surface along repeatedely "juvenated" fracture systems and would have been mainly discharged into the sea as exhalations, a process which still takes place today.

The Mississippi Valley type was, therefore, chosen as the main example because it involves not only immense quantities of ore, areas of deposition and time periods, but also because it evoked discussions even very early, and because this type of deposit is spread over the entire globe. Of course, much still remains to be explained. A more recent paper, which should not go unmentioned, is the excellent study by Stanton (1958) on the "Abundances of copper, zinc, and lead in some sulfide deposits", which has notably contributed to the strengthening of the syngenetic concept.

In addition as well only recently an outstanding paper has been published by Snyder and Odell (1958) on "Sedimentary Breccias in the southeast Missouri lead district", which regards breccia formations as syngenetic. It is probably no great step from this cognizance to the syngentic explanation of the small scale fabric and finally to that of the ore structures.[6]

A striking similarity with the Mississippi Valley and with the English lead-zinc deposits in the Paleozoic sediments is incidentally also observed with regard to the north Swedish deposits in the same sediments of the same age. A profile in Laisvall in northern Sweden (Grip, 1948, page 9) could almost be interchanged with with cross-sections from the lead belt in Missouri. Grip does not commit himself to any genetic interpretation.

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[6] As the author found out only recently, Professor Maucher has already in 1956 voiced the assumption in Mexico City that the Mississippi Valley deposits could be syngenetic and exhalative.

h. The Iron Deposits (mostly Precambrian) of the Lake Superior, Cerro Bolivar, Labrador, Itabira, etc., Type

The same duality of syngenetic type and epigenetic interpretations can be recognized here, too. In passing we only want to mention that on the basis of examinations in Peru (1956c) and at the Lake Superior (1958b and 1958e) during the years from 1952 to 1957, an originally syngentic-supergene and/or syngenetic-hypogene theory seems to be more probable to the author than the various epigenetic interpretations. The criteria which were established at that time are again amazingly similar to those that have become known to us through Borchert (1954 and 1955) and Ramdohr (1953). While for example, at the Lake Superior quite positively epigenetic-supergene, rearrangements (most likely in the ground-water zone) must have taken place, it is still very probable that this might have been an exhalation of Kiruna magma, as in principle suggested at a very early date by Gruner (1924) perhaps in part leaning toward Van Hise and Leith (1911), or they may be strictly sedimentary ore formations (see P. Niggli, 1952, Borchert, 1952, Hegemann and Albrecht, 1954 and 1955, and others).

The strong decrease in the amount of developments of such and related deposits since the Archeozoic has been related by the author in a recently published review (1958e) to decreasing degassing of the earth's crust.

i. The Hornstone Problem ("the chert problem")

Animated discussions on the tremendous amount of chert existing in limestones, in dolomites and clays come up again and again in the Middle West of the U. S. A., as well as in many other areas. These cherts appear as nodules, porous skeletons or as lenses or stages transitional between these forms.

The interpretations vary again strongly. Where one group regards it as self-evident that the chert was deposited as sedimentary silicate-gel, others are of the opinion that chert masses, which often appear in several generations in breccia ore, such as in the tri-state district, have been formed epigenetically-hypogene-hydrothermally by voluminous replacement of whole dolomite and limestone horizons (Fowler et al., 1934, and others).

Others think of epigenetic-supergene formation as the best solution, whereby it is assumed that the ground-water has rearranged SiO_2 while dissolving complete strata of dolomites and limestones. The greatest number of geologists in the Middle West, however, represents the syngenetic concept and introduces the silicate "raw material" volcanic-exhalatively, thus hypogene-hydrothermally but syngenetically, or as a product of weathering, thus supergene syngenetically. Winkler (1925) and others suppose that sponges were the silicate collectors, and after their death were the suppliers of silicate.

Good criteria for syngenetic nature were recently published by Harris (1958). He described desiccation polygons with chert concretions as centers. Linck and Becker (1926) produced chert experimentally over 30 years ago. An extensive compilation on the geochemistry has issued from the pens of Folk and Edward (1952), and it throws light on factors which have to be considered in the case of epigenetic or syngenetic interpretations. Kumm (1926) thoroughly weighed the criteria for and against pre-, syn- and post-diagenetic origin for concretions such as chert and mentioned many earlier works which were not considered by Harris, Pantin, Fowler and others who wrote on the chert problem.

On syngenetic chert and jaspilites, which as a rule are associated with keratophyres and jaspilites, the author will report in the forthcoming spilite monograph. Putzer (1958) recently published a beautiful paper on the cryptomelane and jaspilite deposits in Brazil. This work is loaded with syngenetic criteria.

j. Carbonate rocks and deposits (predominantly dolomite, magnesite, etc.)

The entire doubtfulness and also difficulty of differentiation between epigenesis and syngenesis appears again in the siderite-magnesite-dolomite-limestone problem. Where do the borders between syngenetic and epigenetic processes lie in this case? Which criteria can we use? Which arguments have to be rejected already because of purely logical reasons, and which research methods best lead to the goal?

On this field of problems too there is an almost unlimited amount of literature, and what can be mentioned here are again only some "typical examples" which were selected from a great number of papers.

A well-documentated new paper, which among other subjects also discusses dolomitizations, originated from E. Genge, Jr. (1958). Genge showed dolomite veins in Mesozoic rocks folded during Alpine orogeny, but also calcite and calcite-dolomite veins, which traverse a limestone, limestone-dolomite or dolomite rock in all directions. At some place there seems to be a connection between the geometry, the content of dolomite and the veins; in most cases, however, a lot speaks against a connection. If for example, as Genge showed through pictures and words, the wall of a dolomite vein is dolomitized, and the other is made up of limestone. One has to be on one's guard to speak of a dolomitization which begins at these veins. As Genge showed these veins could also be much younger, and one will

agree with him that "in detail... little regularity can be seen in the occurrence and distribution of dolomite and limestone".

If, as in Genge's Figure 4, Table V, a decrease in the thickness of dolomite along a suture surface occurs, or, as in Figure 1, Table V, a calcite vein traverses right in the middle of a limestone zone, then we should not forget that the fracture lines in a firm body usually follow zones of weakness; and as the stress or tensile properties of dolomitic and limestone portions as a rule are different, it is to be expected that the veins usually either go through dolomitic portions or through the limestone portions. Now if they traverse the dolomite, we are tempted to speak of dolomitization, but if they traverse the limestone, we do not speak of a "limestonization", but we simply assume that the limestone veins were formed by lateral secretion. — In the case of Figure 4, Table V, there exists also the possibility, that the dolomite was formed syngenetically, which is the same as a change in condition at deposition, and which normally might lead to a suture surface.

These are rather simple trains of thought, which are probably designated by most people as "common sense". But it is astonishing how easily we simply step over the barriers of common sense when the question is one of proving a preconceived opinion. These opinions, however, are often partly or completely subconscious, and thereby also the ignoring of the criteria which speak against our preconceived opinion. We should bring out and make conscious, as far as possible, what fled into our subconscious or what even never reached the conscious.

One frequent geometric relationship applying here and to sulfide deposits, which is interpreted genetically, is "aggressive" or "positive" and "regressive" or "negative" grain boundaries. These are often erroneously used as simple direct proofs of replacements, although in most cases the inspection of the third dimension would already show this interpretation to be a circular argument. Yet, many authors on many occasions have referred to it, among others P. Niggli (1948, page 192, figure 112) with the aid of a clear diagram, and also the author in various papers (e. g. , 1954a and 1957c). However, again and again we find the cited geometry misunderstood in the kilometer range of outcrops, in the centimeter range of hand-specimens and in the millimeter or micron range of thin sections and polished specimens. This misunderstanding is the confusion between Δc, Δr and Δt, which was mentioned at the outset.

Naturally, many more similar, in themselves simple, geometric criteria could be named of which many are related to sedimentary-petrographic criteria mentioned before. Here we shall only call brief attention to a number of factors which often are also disregarded or which are used "circularly" as clear proofs of processes which only can be analyzed by a finely woven and systematic sequence of indications and/or previously proved indications. These are e.g. , color and hardness differences, which are brought out by erosion and which often too soon are interpreted as differences in the composition or even are used as proofs of introduction of material, in cases where, on scrutiny, there is no chemical or mineralogical difference. Grain-size differences too often play the same role, and for example in the tri-state lead district, to the wrong assumption that only the breccia and fracture zones are dolomitized. The dolomite is, truely, only coarsely crystalline in these zones and therefore visible, while the fine-grained surrounding rocks often are implied by assumption to be free of dolomite. In reality, the dolomite zones as a rule possess a much larger and irregular extension than the narrow ore-rich fracture and breccia zones.

This discussion of the "magmatically oriented" epigeneticists on the "impregnation deposits" in a remarkable way is identical (and often word for word) to the proceeding of the "migmatic" epigenticists, namely where these men speak about their diffusion-like granitizations, about "basic fronts" and other similar processes.

Genge answered the question of syngenesis and epigenesis in favor of a chiefly late diagenetic dolomitization (page 183), but he stressed, that with this "it is not stated...that no primary or early diagenetic dolomites or dolomitic portions occur in limestones" whereby we perhaps could add that especially the late limestone matrices of dolomite breccias become understandable through a syndiagenetic interpretation.

Important and for our discussion of general validity is also the following statement by Genge – "These dolomite formations, however, cannot always with certainty be distinguished from the much more conspicuous younger transformations by which they are covered for the most part".

Often we not only have remarkable trouble in seeing geological phenomena in three dimensions, but also the fourth, the time dimension often acts stubbornly. To consider details of a geological body to be genetically ensnarled, even if perhaps they have nothing to do with each other on a time basis, can also carry us so far that we regard something as epigenetic which is syngenetic, and visa versa. Younger transformations and tectonic deformations with or without migrations of material have to be, as far as possible, distinguished from older or even original structures, textures and compositions.

Now it may seem that this discussion is superfluous and that the syngenetic nature of dolomitizations is self-evident. But if we look about in the literature in connection with deposits in

limestones and dolomites, we see, that often the interpretation changes from syngenetic to epigenetic as soon as we are dealing with rocks that are minable – thus with ores. For example, the dolomites, and as already mentioned, also the chert of Paleozoic sediments in the Middle West of the U. S. A. at least near the minable deposits were explained by different authors as hydrothermal rock constituents, or as epigenetic rock constituents that were formed by ground water. Behre (1947) for example, wrote (page 542) "... A definite localization of a given carbonate (e. g., dolomite) to the close neighborhood of the ore rules out its 'sedimentary' origin, as shown in the tri-state district by Fowler and Lyden..."

Now we can question: How is it then if the ores too show sedimentary origin? (see Fowler et al., 1934). The epigenetic nature of the ores themselves is an assumption, and for now can hardly serve as a proof of the epigenetic origin of the dolomite zones. The author recently showed that the dolomite and chert formation, no doubt with much greater probability, must be interpreted as syngenetic, as also the main mass of the ores per se.

Even in relation to the Leadville district, which today many cite as an ideal example of hydrothermal replacement, dolomitization and mineralization had already been mentioned as syngenetic at one time (Pošepný, 1893/1902), after Emmons in 1886 (cited by Lindgren, 1933) supported an epigenetic-supergene formation. In a new paper on the deposit near Gilman, Lovering (1958) showed that on one hand the dolomitization occurred, most probably, at approximately 300°C, but that the mineralization partly occurred below 150°C.

In a similar way the magnesite and siderite deposits in the eastern Alps are explained by one school (e. g., by Leitmeier, 1953) as essentially syngenetic and by another school (e.g., by Clar, 1953, Friedrich, 1953 and by W. Petrascheck and W. E. Petrascheck, 1950) as epigenetic. We are dealing here, as in the case of the Bleiberg and Mississippi Valley type, with essential problems of Alpine or American geology, namely with the question whether we can speak of a magmatic or regenerative Alpine metallogenesis or whether the majority of these deposits is syngenetic, and therefore much older. It is probably clear that these questions can much more easily be solved if they can be discussed in a larger, worldwide scope and with more comparative material, in particular also on the basis of comparisons with experimental results. As may be seen from this work we are dealing largely with the same criteria which wait for a better and more generally valid answer.

k. Autigenic and Allothigenic Portions of Rocks

From definite ore deposits we have now slowly advanced to actual rocks and here again we meet the same polarity of interpretation. It shows in many relationships, but perhaps most markedly in the problem of autigenetic and allothigenetic minerals or mineralizations. To give only one example, the albite content in various metamorphic rocks is interpreted by one group as an additive mineralization product, but by the other as autigenetic. Albite contents of that kind for example occur in the Casanno slates of the Alps or in metamorphic rocks of the Monte Rosa massifs. The criteria for and against epigenetic albitizations again are quite similar to the other discussions on epigenesis and syngenesis. The questions chiefly center around the interpretation of fabrics, which are looked at by some as replacement fabrics and by others as simple metamorphic recrystallization or simple syngenetic crystallization fabrics. Furthermore, the question is one of interpretation of compositional gradients, which also are ambiguous at first approximation, and which are looked at by some as proof of introduction and material migration, and by others simply as original differences in the composition.

The literature on such rocks and processes is extremely voluminous, and a bibliography which is only approximately complete would comprise hundreds of papers. Here we have to be content with the few indications. Concluding, we shall only refer to the outstanding comparative lithological studies of autigenetic sediment formations in ocean basins, as published among others by Strachow (1956). Ore genesis studies on autigenetic and allothigenetic formations naturally cannot circumvent sedimentary-petrographic information, but especially in the U. S. A. this has been paid too little attention, despite excellent books and journals (e. g., Shrock, 1948 and the Journal of Sedimentary Petrology).

l. Fillings of Fossils ("replaced or mineralized fossils")

The discussion of the age of replaced fossils centers around the same points. Sedimentary petrographers, stratigraphers and also paleontologists (as far as they are interested in the mineralogic composition of their fossils) usually suppose that the material which today is present in a fossil was deposited at the time of diagenesis or even earlier and that later in general only unessential and entirely local rearrangements have occurred.

However, if we read papers on mine areas, especially those which were published in the U. S. A. in the first half of the century, then we usually come to the expressions "replaced fossils" or "mineralized fossils", whereby these terms, almost without exception, are conceived as epigenetic. The discrepancy in interpretation is clearest perhaps in the case of papers on petrified or "mineralized" and "replaced" wood

in the western states of the U. S. A. The huge masses of petrified wood are usually regarded as syngenetic or syndiagenetic silicifications (see Murata, 1940, and Amstutz, 1952b, 1954b, and 1958k). But as soon as sulfides or even uranium minerals occur in the wood many speak of epigenetic replacement although from a purely geometric and geochemical standpoint, we are dealing with the same phenomenon.

Also in this field we are therefore looking for stronger criteria for the age of a rock portion. In the case of plants and animals it should perhaps be a little easier to find good clues, as we often know the plant and animal tissues in the living and dead state and therefore now and then should be able to find a clue for the time of the "mineralization". (This is being attempted at the present time at the Missouri School of Mines through a thesis.)

In a short description of a Kupferschiefer deposit in Peru the author designated the cells of Permocarbonaceous tree trunks which are filled with copper glance and bornite as "replaced cells in a fossil silicified tree", because he simply without thinking about it, copied the expression from Bateman's textbook. However, in this case, the cells have most probably been filled pre- or syndiagenetically with chalcocite and bornite. It is probably advisable to reserve the expression "replaced" for later changes, and not for the "replacement" of water or plasma by inorganic substances in the water. This type of fossilization is hardly to be designated as a replacement process, but simply as a filling in, whereby apparently the minerals precipitated in the shells and the interior of organic materials differ from those in their environs, probably simply because often small, relatively-protected euxinic milieus exist in the interior of plants and animals.

This section too shall not be concluded without an indication that in this field, experiments have already been made some time ago which succeeded in attaining syngenetic petrification in the laboratory (Sabbatoni, 1920).

m. The Genesis of Oil Deposits, Tar-sand, etc.

The preceding examples, as also most which follow, are chosen from the field of petrography and the study of ore deposits, whereas the "dimorphism" of the genetic interpretation extends to the field of petroleum geology and related disciplinary branches as well. Probably the clearest exemplification of the two lines of thinking appeared in 1955 in the Bulletin of the American Association of Petroleum Geologists and consisted of a fundamental syngenetic study by Corbett and four epigenetic replies by Gussow, Hamilton, Hume, and Sproule. Corbett replied to the four epigeneticists in a 13-page answer which was published in the same issue. Since this scientific model tournament, worthy of imitation, numerous valuable contributions to both sides have been published. Here only the short summary of Professor Lange (1955), who joins largely the epigenetic side, shall be mentioned and the following quotations originate from his work. Lange writes (page 126) —

"The dispute on the genesis of the oil in the deposit which is known as 'Athabasca tar-sand', is debated by 'insituists' and 'migrationists'. According to our customary terminology we thus are dealing with an exchange of views between syngeneticists and epigeneticists.

"Corbett holds the view that the petroleum of the tar-sand originated syngenetically with the sand deposits in which it occurs today. He proceeds from the idea that in the limestone strata of the McMurray sand strata countless plant remains are present. During their deposition, according to his opinion, great masses of humic acids must have been formed. Thus he reaches the conclusion that these humic acids form the mother substance of the petroleum of the tar-sand. In order to make his view plausible, he constructs a huge lagoon which is supposed to have existed in the time of McMurray. In this lagoon the petroleum shall have formed by the condition that the river water which was strongly enriched with humic acid hit salt water, whereby then the petroleum should have liberated itself from the river water which contained the humic acids in the colloidal state.

"Corbett points out that the Carboniferous, Cretaceous and Tertiary were periods in which, beside the huge coal deposits, also originated the most important petroleum deposits, syngenetically with the corresponding sediment deposits from humic acids. He is of the opinion that the asphaltic oils of the tar-sands are a preliminary stage for the formation of light oils which under the influence of pressure and heat at greater depths of the earth formed from originally asphaltic oils.

"Among the contributions to the discussion the one by Gussow attracts attention which most consequently and thoroughly turns against the theory of Corbett. According to him the oil of the Athabasca tar-sands accumulated itself in a genuine stratigraphic trap. He rejects, just as the other participants in the discussion, the origin of petroleum from humic acids. Furthermore, he cannot agree with Corbett's concept, namely that the heavy asphalt oils to some extent are the mother substance of light paraffin oils. According to him asphaltic oils in general developed in flat structures along old erosion surfaces or near dislocations from originally light oils through oxidation. The tar-sands in the Arbuckle Mountains of Oklahoma, the Santa Rosa deposits in New Mexico, many tar-sand occurrences of California, the very heavy asphalt

oils in the upper sands of the Maracaibo basin and in the "tar" strip along the outcrops of the Orinoco Basin in Venezuela according to him are further examples of the same type of formation of asphaltic oils as it was observed in the Canadian tar-sands.

"Hamilton objects to Corbett's theory that the carbon content in the aqueous solutions (which contained colloidal humic acid) must have been less than the amount of the carbon of the lignitic substances, which still today are present in the sands as fossils. According to him the greatest content of lignitic substance in the McMurray sands is only 0.5 percent. Thus one cannot believe that the humic acids originating from them should have been enough in order to form such a huge quantity of petroleum, as they occur in the Athabasca tar-sands.

"Sproule rejects that the tar-sands could have been deposited under lagoon conditions. The partly cross-bedded sands represent a deposition near the beach line of the open ocean. So far it is supposed to have never been claimed that they were deposited in a lagoon. Also the deposition of humic acids which eventually reached the ocean could not have happened in the strip of coast in which the McMurray sands were deposited.

"In his reply Corbett grants that the formation of petroleum from humic acids could not have occurred in a lagoon, but indeed in a bay or in a gulf of the open sea. In contrast to this, he still rejects the assertions of his oponents that the asphaltic petroleum could have formed in a stratigraphic trap. Especially he turned against Gussow's contention that the petroleum of the tarsands migrated from Jurassic rocks into the tarsands.

"The most important point of difference between the conceptions of the two scientific directions is the question of migration possibility..."

Following this account, Lange gives his own contribution to the discussion.

This discussion on the genesis of petroleum deposits is reproduced so completely here because it seems extremely remarkable that in a branch of geology, which, seen from the outside, is an entirely different branch, the same polarity of views exists again. But not only that, the parallelism and similarity goes so far that one can even see the same ideas and discussion move in the same channels, and most likely similar mistakes in thinking are committed. The migration possibility and the "Degsamkeit" are again located in the center of uncertainty. The relativity of our knowledge and of the possibilities for observation again becomes obvious.

A hardly-acceptable restriction is the argument that "the amount of the carbon of the lignite which still today occurs as fossils in the sand" directly permits to conclude on the "carbon content of aqueous solutions which carried colloidal humic acids". The lignitic substances are not the only parts of plants which consist of carbon and form humic acids. And in addition in a physicochemical system – and this is what we are dealing with in the case of ocean-water — the substances precipitated at any one time do not necessarily create, even in the least cases, an exact chemical image of the composition of the solution or melt. The latter though, influences the time of precipitation and the composition of the precipitating phase of the deposit. However, components can be very active during precipitation which generally never precipitate by themselves but which always remain in solution. One example important for our discussion is the formation of dolomite, pre- or syndiagenetically. As Teodorowitsch (1955) and others have shown, NaCl for example brings into closer contact the solubilities of $CaCO_3$ and $MgCO_3$ in seawater. So dolomite is formed because of the presence of relatively high NaCl contents, but whereby NaCl is not precipitated. The dolomite problem has, as was already shown, considerable meaning for the genesis of the Mississippi Valley type of deposits.

In the section on extra-terrestrial theories the two extreme epigenetic theories on the formation of petroleum deposits will be reported.

(Part 2 of 2 will appear in the March issue of IGR)

CLIMATE AND OIL GENESIS[1]

by

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translated by Royer and Roger, Inc.

ABSTRACT

Studies of the Caspian Sea, the Barents Sea and others, show that the rate of accumulation of organic matter in sediments and the nature of its initial change is largely dependent on climate. All known large oil pools are located in basins which had a warm environment at the time of deposition. Occurrences of gas in colder zones were associated with coal rather than oil. Exploration for oil in polar areas should be restricted to rocks known to have been deposited in warm paleoclimatic conditions. All evidence denies the inorganic theories for the origin of oil. --M. Russell.

* * *

Oil genesis by anaerobic transformation of autochthonous organic matter of plant and animal origin deposited with sediments is presently accepted by an overwhelming majority of geologists. Thus it is important to determine the role of climate in the accumulation and transformation process of organic matter in present-day sedimentation basins and to compare these patterns with facts known of the geologic past.

Hydrobiologists have determined that an increase in mean annual temperature, salinity, duration of light (naturally within vital limits) increases sharply the productivity of water organisms; at the same time, emphasis is placed on the particularly important role of temperature. This is well illustrated by the results of calculating quantitatively the biologic mass (the average annual amount of organic matter in living organisms) and the annual production of the principal faunal and floral components in the Barents, Caspian and Black Seas, as carried out by L. A. Zenkevich (1947-1951) S. V. Bruyevich (1939), O. A. Radchenko and N. B. Vassoyevich (1958). The results are presented in Table 1.

We can see from the table that for one square kilometer of the Barents Sea there live, on an average, 176 tons of water organisms which in a year produce 210 tons of crude organic mass. In one square kilometer of the Caspian Sea there is a total of 108 tons of hydrobionts which, however, owing to great fertility and short span of life (as contrasted with cold-water organisms) reproduce annually about 3, 060 tons of crude organic matter. In the Black Sea, which is warmer than the Caspian, there live on one square kilometer 136 tons of hydrobionts which annually reproduce about 6, 900 tons of crude organic matter.

The amount of organic carbon in the sediments of the Barents Sea ranges between 0. 15 and 3. 12 percent (Gorshkova, 1957). In the sediments of the Black Sea there is from 1 to 5 percent organic carbon; in Caspian Sea clay from 0. 26 to 2. 25 percent (Strakhov, et al, 1954). Judging from maps showing the distribution of organic carbon, Black Sea sediments are approximately 1. 5 times richer in organic carbon than Barents Sea sediments. The Caspian Sea sediments, on the other hand, are somewhat more deficient in organic carbon than the Barents Sea sediments. Thus, the organic matter content buried in sediment depends, it seems, little on the biologic productivity of the basin. However, we can draw this conclusion only if we do not consider the extent of dilution of organic matter deposited on the bottom with clastic material.

TABLE 1. Character of the biologic productivity of the Barents, Caspian, and Black Seas

Groups of hydrobionts / Weight: millions of tons	Barents Sea (area 1, 360, 00 km^2)		Caspian Sea (area 436, 000 km^2)		Black Sea (area 411, 550 km^2)	
	Average biomass	Annual production	Average biomass	Annual production	Average biomass	Annual production
Phytoplankton	4. 0	200. 0	3. 5	1000. 0	13. 5	2700. 0
Zooplankton	45. 0	45. 0	5. 0	150. 0	1. 5	45. 0
Phytobenthonic forms	5. 0	5. 0	3. 0	3. 0	20. 0	40. 0
Zoobenthonic forms	150. 0	30. 0	30. 0	180. 0	20. 0	40. 0
Fish	35. 0	6. 0	6. 0	3. 0	1. 0	0. 17
Total	230. 0	286. 0	47. 0	1336. 0	56. 0	2825. 17

[1]Translated from Klimat i Obrazovaniye nefti: Saratov State Univ.; Izvestiya Vysshikh Uchebnykh Zavedenii, Neft i Gaz, v. 2, no. 9, p. 11-18, 1959. Reviewed for technical content by J.W. Clarke.

As S. V. Bruyevich (1949) points out, one ton of sediment is accumulated over a period of 2,300 years in the deep southern part of the Caspian. In the Black Sea one ton of argillaceous calcareous clay (at a depth of 200 to 1,500 meters) is accumulated over a period of 1,070 years. In the deep part of the Barents Sea (north and south of the Tsentralnaya elevation) one ton of sediment is accumulated in 25,000 years.

If we turn now from a comparison of the relative concentration of organic matter to a comparison of its absolute mass accumulated in a unit of time, we see that in the Caspian Sea in a unit of time there is 11 times more organic matter and in the Black Sea 23 times more organic matter accumulated than in the Barents Sea.

As we know, a prerequisite for the initiation of the oil genesis process is the intensive accumulation of clastic material (based on a stable bottom submersion) and the presence in sediment of a definite minimum quantity of nonoxidized organic matter capable of inducing an active restoration process within the actual surface part of the sediment. V. V. Veber (1956) considers that in order to form in the sediment a restoration condition, an organic content of from 0.4 to 3 percent in the sediment (depending upon the granulometry of the sediment) is sufficient. It is not difficult to see how insignificantly small the relative content of organic carbon would be in the Barents Sea sediments if the extent of its dilution with terrigenous material were the same as in the Black or Caspian Seas, which are considered by many investigators as the present-day analogues of ancient oil-producing sedimentation basins.

In the opinion of V. V. Veber (1956), A. I. Gorskaya (1956), P. V. Smit (1956) and others, the oil genesis process is possible only in the presence of anaerobic conditions in the surface part of the sediment, because, when organic matter remains for a long time under oxidizing conditions (during the fall to the bottom and in the surface part of the sediment) the potentially crude oil matter in it is oxidized so that in an anaerobic condition which originates below the surface of the sediment, this matter will not be transformed into hydrocarbons.

The hydrodynamic factor is of great importance under the preservation conditions of organic matter deposited with sediments. By complete vertical circulation customary in Arctic and Subarctic Seas dead organisms, owing to aeration of the total water column and surface part of the sediment, were under oxidizing conditions for a long time. All this leads to the fact that in an anaerobic state which develops in them below the sediment surface a new genesis of hydrocarbons fails to occur, because a great part of the potentially crude-oil organic matter at this time is already in an oxidized state. Results of studying the organic matter of marginal (in this case cold water) and southern seas, bears out this fact. Thus, A. I. Gorskaya (1956) determined that in the bitumens of the sediments of marginal seas there was approximately half as much hydrocarbon as in the sediments of the Caspian and Black Seas (average hydrocarbon content in the sediments of marginal seas was 6.8 percent, in the Black Sea sediments 11.7 percent; in the Caspian Sea sediments 13.4 percent).

In the warm-water basins, in contrast to cold-water basins, anaerobic conditions for interring dead organisms are brought about more easily. Owing to poor aeration of the bottom part of the water column (due to insufficient cooling of the surface layer of water) and also because of intensive accumulation of organic matter, the restoration medium in them originates in the surface part of the sediment. At the same time, as was made apparent by A. I. Gorskaya (1956), V. V. Veber (1956), P. V. Smith (1956) and others, the amount of hydrocarbons in the bituminous part of organic matter increases as the sediment submerges.

Thus, climate has a great effect not only on the intensity of accumulation in organic sediment but also on the character of its primary transformation. How acceptable these apparent patterns are for the geologic past may be determined by explaining the spatial relation of presently known oil fields to paleoclimatic zones that correspond in time to the age of oil extractable from one or another field. For this purpose, we have conducted a number of paleoclimatic reconstructions (1955) assuming as a basis the paleogeographic constructions of A. D. Arkhangelsky, N. M. Strakhov, A. N. Krishtafovich, L. B. Rukhin, V. A. Vakhremeyev, and other geologists and paleophytologists.

Space does not permit us to illustrate the paleogeographic schemes which show the dependence of spatial distribution of oil fields upon climatic conditions. Therefore, only a schematic representation of the probable northern boundaries of the oil perspective climatic zones for several periods in the geologic past is given here (figure 1).

From analysis of the paleoclimatic reconstructions we conclude that in the geologic past intensive generation and anaerobic interment of crude-oil organic matter were characteristic only of warm-water sedimentation basins. This is confirmed by the spatial distribution of presently known commercial oil fields which, as a rule, are concentrated around ancient zones of intensive carbonation and around zones that exhibit other high atmospheric-temperature indicators. Moreover, an overwhelming majority of fields which provide more than 99 percent of extractable oil, occur in low or

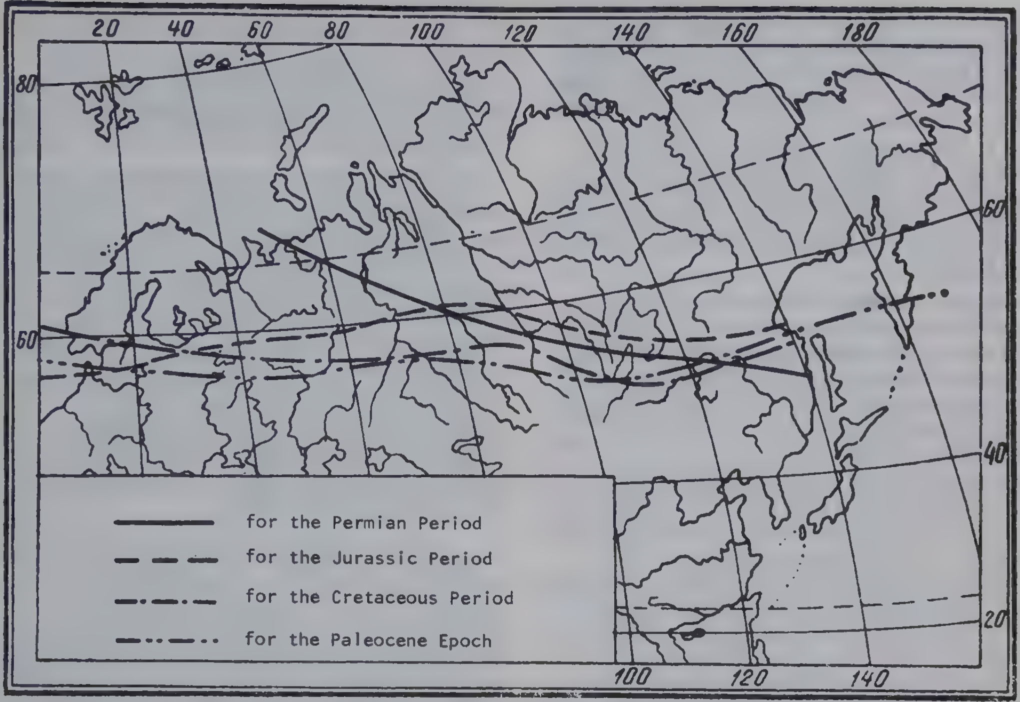

FIGURE 1. Schematic diagram of probable northern boundaries of oil perspective climatic zones for several periods of the geologic past

middle latitudes.

Thus, warm climate during the sediment-accumulation period is a prerequisite for the origin of oil fields under a favorable combination of other factors which contribute to the formation, accumulation, and preservation of oil.

Climatologists have proven that high latitudes, in contrast to low latitudes, are characterized by minimum stability of climate. Hence, when planning oil prospecting surveys within any region in high latitudes, we must evaluate the climatic conditions which existed during the accumulation period of sedimentary layers to ascertain oil prospects. Unfortunately, this had not been done in the oil prospecting surveys of northern Siberia; results of oil prospecting surveys within the Khatangskaya, Leno-Vilyuyskaya, Ust-Yeniseyskaya depressions and in the northern part of the West Siberian Lowland bear this out.

Several hundreds of oil prospecting wells were drilled in these areas. This, of course, is a small number for such vast regions. However, if we compare the effectiveness of oil prospecting surveys in northern Siberia with the results of oil prospects in low and middle latitudes, we cannot explain the failure of oil prospecting surveys in high latitude depressions simply by a small drilling area or by physico-geographic difficulties because the first oil deposits of presently known oil-bearing provinces were discovered, generally, during drilling of the first few prospect wells.

The failure of oil-prospecting surveys in the Khatangskaya, Ust-Yeniseyskaya, Leno-Vilyuyskaya depressions and West Siberian Lowland should, first of all, be explained by the fact that the sediments of Mesozoic and Permian age were formed basically under boreal conditions unfavorable for oil genesis, as a result of which they do not contain genetically associated commercial deposits of oil. We can determine the cold-water state of Permian and Mesozoic north Siberian basins by the specific characteristics of the sedimentary layers accumulated at that time, expressed by impoverishment of the specific composition of fauna, character of floral complexes, negligible limestone distribution and abundance of nondecomposed angular nodules of feldspar, which commonly form the basic part of the clastic material of the sandstones.

Thus, from V. I. Bodylevsky (1957) data there existed in northern Siberia during the Jurassic period a total of three genera of ammonites while in the Caucasus twelve genera were represented. The Permian faunal complex was also deficient in species. V. A. Vakhrameyev (1957) points out that during the Mesozoic in northern Siberia, there was a predominance (during the late Cretaceous) of coniferous ginkgo and coniferous-deciduous trees

with deciduous foliage from ginkgo trees and from most deciduous Angiospermae and with clearly expressed annual cyclizations on cross-sections of petrified wood which does not exist in the southern provinces. There were no woody or tree-like ferns typical of the southern provinces, in northern Siberia. M. F. Neyburg (1954), stresses analogous features (annual rings, absence of ligneous, Lycopodium-like characteristics, etc.), of Permian vegetation in northern Siberia (Tunguskaya Oblast).

During the oil prospecting surveys in the Mesozoic sediments of the West Siberian Lowland and the Leno-Vilyuyskaya depression, gas fields (the Berezovskiye and Tas-Tumusskoye) were discovered; this is considered by a number of geologists as indisputable proof of the oil prospects of these Mesozoic depressions.

Commercial gas deposits are not always genetically associated with oil. Quite a few facts have been gathered by now which attest to the genesis of large gas deposits from the metamorphism of coal, shale, and plant detritus. Commercial gas deposits resulting from regional metamorphism of Pennsylvanian shale and coal are well-known in the Arkanzassky [Arkansas?] coal-bearing basin, where 22 gas-bearing sectors are being exploited. The initial well outputs here have reached 3,000,000 cubic meters per day (Uspenskaya, 1950). Commercial development of gas deposits genetically associated with coal-bearing deposits is being carried out in Poland (Mitura, 1958) and Japan (Koslov, 1959). In the summer of 1958, drilling of wells was begun for the purpose of utilizing the energy of coal gas in the Kuznetz coal fields.

We should note that gas deposits genetically associated with coal, shale and dispersed organic matter are characterized not only by the significance and stability of gas feeder and well output, but also, in several cases, by the presence in gas of heavy hydrocarbons. Kravtsov (1958) writes of the presence of a large amount of heavy hydrocarbons as much as 12.5 percent, in the coal gas of the Kuznetz coal fields: "heavy gas is being recovered in the Kvinton field [Quinton, Okla.?] (Arkanzassky coal-bearing basin)."

In the Mesozoic sequence of the West Siberian Lowland and Leno-Vilyuyskaya depression we have a number of beds enriched by coal-fixed organic matter (in the Leno-Vilyuyskaya depression a number of large coal fields are associated with the Mesozoic deposits) which under corresponding favorable conditions, during regional metamorphism, could be a source of large gas accumulations. The presence of coal-fixed organic matter and coal do not contradict the existence of a boreal climate in these regions during the period of formation of Mesozoic strata, because we are in complete agreement that from the end of the Paleozoic and especially, in the Mesozoic, coal was formed not only in warm zones but also in boreal zones. However, we cannot at present simply resolve the problem of the genetic relationship between the Berezovsky and Tas-Tumussky gas, on the one hand, and Mesozoic deposits, on the other.

Thus, Cretaceous sandstone deposited on a crystalline basement (Sverchkov, 1958) is the basic gas-bearing unit in Berezovo. We have not excluded the possibility that Paleozoic deposits (which encircle the Berezovsky terrace from west, north and east) are the source place of the Berezovsky gas, where numerous immediate oil-bearing indications are known. The Chuelsky gas gusher, obtained again from an underlying zone — no longer from the Cretaceous but from the Upper Jurassic — is further proof of the great probability of a genetic relationship between the Berezovsky gas and the Paleozoic beds.

Gas in the Tas-Tumusskaya section, according to data by G. V. Barkhatov and others (1957) was extracted from the Lower Jurassic. If a stratigraphic affiliation of productive units was determined from the data given in the article, a genetic relationship between Tas-Tumussky gas and Mesozoic deposits is hardly probable, because the lower part of the Lower Jurassic from which the gusher was derived was composed primarily of sandstone, whereas the Kelterskaya series (Triassic) lying below was deposited under oxidizing conditions unfavorable for oil formation. Hence, too, the Tas-Tumussky gas is most probably genetically associated with the Paleozoic (Permian or Cambrian) deposits.

In April 1958, in the southeast part of the West Siberian Lowland, an oil flow (producing 40 liters a day) was obtained from Middle Jurassic deposits on the Nazinskoye uplift. The Nazinskoye uplift is situated south of the probable northern border of the oil perspective climatic zones during Jurassic time. However, in this case, we cannot resolve in simple fashion the problem of the genetic relationship between Nazinskaya oil and Jurassic deposits because, in the opinion of S. I. Mironov, V. A. Uspensky and others, oil extracted from the Middle Jurassic beds in the Kolpashevskaya well is genetically associated with Paleozoic layers.

During fairly extensive oil prospecting surveys in the Khatangskaya depression semi-commercial deposits of Permian crude oil were discovered. These deposits could have been formed here during comparatively short warming periods (which probably were a result of warm-water breakthroughs from the southeast. Seams, or interlayers of limestone and gypsum found in a Permian section are proof of this. The features of oil genesis within the Ust-Yeniseyskaya depression also are proof of the

genetic relationship between the oil discovered and Paleozoic deposits (Aleksin, 1952).

We have not excluded the possibility that commercial oil, discovered by the Nazinskaya well, and the oil recently extracted in small quantities from the Malo-Altymskaya well are genetically associated with Jurassic deposits. As in the Permian basin of the Khatangskaya depression but on a smaller scale, formation of oil in these deposits was possible during short warming periods. Interlayers of carbonate materials and a high carbonate content of of the separate or isolated seams found in the Jurassic section are the result. In particular, the results of a study of the oils and bitumens of Siberia made under the direction of S. I. Mironov, have confirmed this fact. Summarizing the results of his studies, S. I. Mironov came to the following conclusion: "The results of studying oils and bitumen-bearing impurities found over the vast territory of Siberia have forced us to direct special attention to the study of the oil-bearing character of Paleozoic rocks, with which the principal oil-bearing units are most probably associated. It is probable that oil in the Mesozoic deposits of the West Siberian Lowand has also migrated from these units" (Putsillo et al, 1958, p. 245; italics are Nazarkin's).

Small oil fields (Umiat, Fish Creek) and gas fields (Gubik, Square Lake, Simpson, and Barrow) have been discovered recently in several places within the limits of the Arctic coast of Alaska [Colville geosyncline: U. S. Geol. Survey Bull. 1094]. From T. C. Histend's data (1957) the Umiat field (about 13.4 million tons) has the largest reserves of oil in this region, while Gubik has the largest gas reserves (about 6 billion cubic meters). The other fields are of semi-commercial value.

The absence of vital data makes it impossible to resolve categorically the problem of crude oil deposits in this region. T. C. Histend, for example, considers that oil deposits within the limits of the Arctic coast of Alaska may be traced back to both Mesozoic and upper Paleozoic deposits. I assume that the oil there has been genetically associated with Paleozoic deposits which are represented, for the most part, as carbonate layers. This is proof of the warm water state of the sedimentation basins. The Mesozoic complex, in contrast to the Paleozoic, is deficient in carbonate layers and is characterized by a boreal fauna. The appearance of commercial fields (Umiat, Gubik) only in the piedmont section of the Brooks Range -- an area of maximum development of bitumen-bearing Paleozoic deposits – is further proof of the Paleozoic age of the oil and gas discovered in northern Alaska.

A small oil field traced to Tertiary deposits located on the southern coast of Alaska in the region of Katall, has been exploited for a long time. Extracting oil only near faults or disturbances has forced American geologists to associate it genetically with underlying Mesozoic and Paleozoic deposits.

In 1957, not far from Anchorage, on the Kenai Peninsula, a large amount of oil was recovered from Tertiary deposits of continental origin (Histend, 1957). The age of the oil discovered in the Anchorage region has not yet been determined just as it has not been determined for the oil of the Katall field. If subsequent studies prove that the oil recovered in these regions is genetically associated with Mesozoic deposits (and not Paleozoic deposits) the location of these fields will not contradict the conclusions which I have drawn, because these fields are located south of the continuation of the probable northern boundary of the oil perspective climatic zones (Nazarkin, 1955, figs. 33 and 35).

Thus, oil genesis (under other favorable conditions) is found to be directly dependent upon the climatic conditions that exist (and which have existed) within a sedimentation basin area. The localization of all presently known commercial oil fields in former warm paleoclimatic zones is indisputable proof of its organic origin because we cannot explain by inorganic oil synthesis the concentration of an overwhelming majority of oil fields in low and middle latitudes where warm climate has prevailed throughout almost all geologic time.

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REPORT OF THE WORK OF THE GEOGRAPHIC-EXPLORATION PARTY OF THE KOLA EXPEDITION OF 1930[1]

by

G. D. Rikhter

• translated by Royer and Roger, Inc. •

EDITORIAL NOTE

Although this work was originally published 28 years ago, translation into English has only very recently been made. Later, even more extensive, descriptions of the Kola peninsula, including this area, have been published in Russian, but they are not, to our knowledge, available in translation. G. D. Rikhter is a well-known investigator of Russia's northern regions. The contribution of this translation of his work for publication in IGR is welcomed. --M. R.

ABSTRACT

The Niva River valley extending from Lake Imandra to the Kandalaksha Gulf on the Kola peninsula has a complex geologic and geomorphic history of Tertiary to Recent faulting, uplift, glaciation, and marine deposition and erosion. The area's crystalline basement of biotite and hornblende gneisses was folded and faulted but only the faulting is reflected in the existing alignment of streams and lakes. Quaternary alluvium, as thick as 80 meters, was deposited in association with two principal southeast-moving glaciers. Several terraces resulted from intermittent lowering of glacial lakes as lower outlets were developed or as the rate of downcutting varied in response to lithologic variations of stream channels. Continuing uplift of the Kola peninsula is an additional complex factor in the geomorphologic development of the area. --M. Russell.

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INTRODUCTION

It was the task of the Geographic Survey Party of the Kola Expedition of the Academy of Sciences of the U.S.S.R. in 1930 to undertake a complex physical-geographic exploration of the valley of the Niva River and a strip of 10 to 15 km adjoining it to the west and to the east; another aim was to search for building materials in these areas in connection with developing apatite deposits. In order to secure the best practical results, we adopted a proposition of Energostroy, along with the assignments of the Academy of Sciences, calling for a more detailed exploration of the Niva River valley at the points where the erection of a new hydroelectric power plant is planned; in addition, we accepted the request to direct the test-hole drilling operations of Energostroy's Geological Party No. 10. For practical reasons, the boundaries of the proposed exploration area were changed. In connection with prospecting for clays and diatomites we explored the western and southern shores of the Lake Babinskaya Imandra. The new project for the development of the Niva River called for concentrated explorations in the region of the Kandalaksha mountain massif. Thus, the boundaries of the explored region extend in the west, from the Savinaya River to the railroad line at the cut at Pinozero, and further northwest to Cheverez Bay of Lake Imandra. Separate routes were run in the area of the town of Upolakshi and of the Peschanaya River (Vuondas); on the north, along the shores of Lake Imandra, and on the eastern part along the shores of Pinozero; on the east, along the Luvenga River; on the south, along Kandalaksha Gulf.

The party consisted of nine persons and worked under the direction of the geographer, G. D. Rikhter, who in addition to the general supervision of the operations of the entire party, directed the explorations of the Niva River valley and, mainly, in the area of the projected hydroelectric plant. The chief of the group, the geographer A. I. Filippov, operated with his collaborators mainly in the region of the Kandalaksha Mountains and Lake Tetyushkino; the scientific collaborator, M. K. Karpun, student of the Geographic Facul'tet of Leningrad State University, worked along the right bank of the Niva River, but he also operated with A. I. Filippov in the region of the Kandalaksha Mountains; the scientific collaborators, A. M. Arkhangelsky and V. F. Tumel, both students of the Geographic Facul'tet of the Leningrad State University, worked on the shores of Lake Babinskaya Imandra; the scientific-technical collaborators, I. V. Maksimov, S. S. Lapin, V. Khlebnikov, V. N. Koshkin, all students of the Geographic Facul'tet of the Leningrad State University, acted as surveyors and collectors. Of great assistance in the operations mentioned above was the collector of Elektrostroy's Geological Party, A. Yu. Pechkovsky, who took the photographs attached to this paper.[2]

Processing of the data obtained by the expedition was carried out under the direction of Professor A. A. Grigoryev, who edited the report.

A party of four men (G. D. Rikhter, A. I. Filippov, M. K. Karpun and I. V. Maksimov) left Leningrad on July 3, and carried out a reconnaissance exploration of the Niva River valley before the arrival of the others. The main operations were then concentrated in the area of the Pinozero rapids near the junction of the Niva and the Pinozero where, according to the first project, the new hydroelectric power plant was to be built. In addition, the persons mentioned above, together with Energostroy's laboratory assistants, the geography students, Tikhomirov and Yegorov, undertook reconnaissance explorations of the entire Niva River valley from its source to the estuary. When the other collaborators arrived the group was divided into two parties which carried out the exploratory operations in the region. From July 1 Energostroy discontinued operations in the area of the Pinozero rapids and transferred them to the south into the area of the Razboynik rapids, where the party's base was set up.

Operations were chiefly aimed at geomorphological and geological exploration. In all the traverses, some 550 rock samples were collected, and on this basis a geological map was compiled. Traverses were accompanied by field sketches based on Gidroelektrostroy's surveys and forestry maps. In order to obtain a better adjustment between field traverses run by A. I. Filippov and by his collaborators in the Kandalaksha mountain region, a small triangulation was established. Fifteen small triangulation towers and four two-stage portable towers were erected on the highest elevations. Observations were carried out by means of the Kuznetsov theodolite, a low-precision instrument. In all, 173 angles were observed on the basis of which the triangulation net was developed. In compiling the map, Filippov followed the method of simplest photogrammetric survey. Soil explorations and geobontanical investigations contemplated by the project could not be carried out because of shortage of manpower.

Operations were terminated on September 27, and after breaking the base camp, the collaborators returned to Leningrad.

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[2]Photographs are not reproduced in this translation because of poor originals. Captions are given as part of the text reference.

The following is a brief historical outline of the explorations in the Niva River region. [No list of references is appended].

The White Sea which surrounds Kola Peninsula appears for the first time on Antonio Vida's map of 1537; until the end of the 17th century on most maps it is shows with its Scandinavian name Gandvig (or Gandvicus sinus). None of these maps gives any details, excepting the Solovetskiy Islands. The Kandalaksha Gulf makes its appearance on maps considerably later; on William Borow's (?) map of 1557 the coast line from Varzuga turns directly south to the estuary of the Onega River.

Kandalaksha (Candelax) is mentioned in Simon van Sallingen's description of Lapland (1591); he also gives a very correct representation of the Kola Peninsula on a map of 1601. It is on this map that the Niva River and Lake Imandra are found for the first time; from then on, Kandalaksha is included on all maps, while the Niva and Imandra disappear again until the middle of the 18th century. The late appearance on maps of Kandalaksha Gulf and of Kandalaksha despite an excellently developed cartography of Murman is explained by the commercial and economical interests of the time. Most of the cartographic data were obtained as a result of trading relations of the Scandinavians and the English with legendary Biarmia, i. e., with Russia's northern districts (mainly Arkhangel'sk), while Kandalaksha, being away from the main trade routes at the end of the White Sea, remained unknown for a long time.

From the time of Olay Magnus' map, a lake, Albus lacus, was shown in the interior of Kola Peninsula, which on some maps had an outlet to the north, on others into the Gulf of Bothnia, and on some others, into the Kandalaksha Gulf near the village of Kandalaksha. On Olay Magnus' map it apparently represented Lake Enare, on later maps, presumably Lake Imandra. It does not appear on Simon van Sallingen's (1601) or A. Bureus' maps (1613), but appears later on Neugebauer's (1612) and G. Gerard's (1613); finally, after 1614 (G. Gerard's map) neither it nor the Niva River appear.

Lake Imandra and Niva River reappear again only on Kirillov's Atlas (1745), and since then they are included with this or that outline in all later maps. However, on all subsequent maps the entire region was represented with considerably less exactitude than on Kirillov's which fact was duly pointed out by Middendorf.

The first description of Lapland and of the region under investigation was made by the Dutchman, Simon van Sallingen. He came to Russia in 1591 as a trade agent for an Antwerp company. Before that he had taken several trips to Karelia and Lapland.

In 1592 he was in the service of the Danish government as an interpreter and government commissioner for the demarcation of boundaries between Russia and Norway, and until 1598 made several trips to Lapland on various duties.

In 1591 he compiled a report, and in 1601, on the basis of his observations, he drafted a map of Northern Europe which is very valuable for the data contained therein.

The first studies of the Niva River basin date from 1834 when Captain Shirokshin explored from a geological viewpoint the shores of Kandalaksha Gulf and the southern part of the Kola Peninsula. Prior to Shirokshin, there existed only a few inventories of the White Sea coasts carried out by hydrographers, such as Lieutenant Titov and the Mate, Seleznev, in 1799; Reinecke in 1827-1832, etc. Shirokshin was the first to point out that in the southern part of the peninsula banded rocks (gneiss, hornblende schists, etc.) prevailed; he also was the first to furnish data on the structure of the Kola Peninsula's interior. In 1840, the well-known geographer, A. Middendorf, member of Academician Bera's expedition, made his way from Kola to Kandalaksha and gave a description of his itinerary both from a topographic and, mainly, geological and petrographic viewpoint. His explorations are particularly valuable for their extraordinary accuracy. In 1842 the same itinerary was followed by the ethnographer Karsten who left a considerable number of works on the ethnography of Lapland. The first botanical studies and collections were undertaken in this region in 1867 by the botanists, Friis and Daa.

From 1868 to 1878, the islands and the coast of the Kandalaksha Gulf were visited by the German mining engineers, Forster and Baldauf, whose task it was to explore these regions for silver. The petrographic data gathered by them were processed and published in 1880 by A. Steltzner.

In 1869 the Aubel brothers carried out geological investigations in the Kandalaksha region. In 1880, investigations were made on behalf of the St. Petersburg Society of Naturalists, N. Kudryavtsev and F. D. Pleske. Kudryavtsev published a very circumstantial report on the expedition giving copious data on the geographical and geological features of the area. It should be noted, however, that N. Kudryavtsev's rather inaccurate observations led him to numerous incorrect conclusions. F. D. Pleske conducted zoological observations published in a separate report.

Some geological and geographical data can be found in the notes of the French geographer, Ch. Rabot, who crossed the Kola Peninsula

from Kandalaksha to Not-ozero, west of Lake Imandra. Petrographic and geological data of this expedition were processed by Sh. Velen. From 1887 to 1892 a joint expedition of Finnish scientists (Ramsay, Petrelius, Chilman and others) operated on the Kola Peninsula; up to the present [1932] the results obtained by this expedition represent the basic material for knowledge of this region. The extremely accurate, elaborate and complete geological (Ramsay, Gakman), topographic (Petrelius) and botanical (Chilman, etc.) observations and data have to a great extent remained unsurpassed. Ramsay was the first to give quite a harmonious and clear picture of the geological structure and history (especially of the Quaternary) of the Kola Peninsula. However, the Niva River basin was touched by that expedition only in passing. In 1888 V. A. Fausek carried out zoological and geomorphological investigations in the Kandalaksha-Kuzomeni area. In 1890 the mining engineer, Melnikov, performed geological and petrographic investigations enroute from Kandalaksha to Kola and compiled a report on his studies. In connection with the projected St. Petersburg-Murmansk railroad, preliminary explorations in the section, Kandalaksha-Yekateriniskaya gavan' (Harbour), were carried out in 1894 by the engineer, B. Rippas. His detailed report contains much data of interest to us. In 1901 the western part of the Niva River basin was explored by the Finnish geographer, V. Borg. His itineraries covered in a dense network the border regions with Finland, while the area interesting us was covered only in part. Petrographic and mineralogical researches on the islands and shores of the Kandalaksha Gulf were undertaken in 1902 by Ye. S. Fedorov who published a series of papers. In 1911 the botanist, Regel, travelled along the Kola road, and published subsequently an independent treatise on the botany and geography of the Kola Peninsula. In 1917 the Geological Committee, in connection with the construction of the Murmansk railroad, organized geological investigations along the railroad under the general supervision of V. I. Sokolov. The section between the Kandalaksha station and the Olenya station was explored by the geologist, N. G. Kassin, whose detailed report contains, along with a geological and petrographic description, a geological map of the region and a brief outline of geological investigations and the literature on this region. In the same year, D. S. Belyankin and B. M. Kupletsky conducted petrographic and geological investigations along the coast of Kandalaksha Gulf and nearby islands. In 1917 the State Hydrographic Bureau of the North carried out a reconnaissance survey of the Niva and Kolvitsa Rivers under the direction of the engineer, I. V. Vovkushevsky. Soil and botanical studies in the region of the Kandalaksha Gulf were undertaken in 1921 by the woman-collaborator of the Northern Scientific-Economic Expedition, N. M. Savich. In 1926 the coast of the Kandalaksha Gulf was explored by the colonization expedition of the Murmansk railroad.

The northern shores of Kandalaksha Gulf in the area of the Kanda River, the village of Kandalaksha and the Kolvitsa River including the southern part of Lake Kolvitskoye were explored in 1925 and 1926 by a group of Moscow geographers (Bondarenko). The investigations were in the nature of a complex geographic study. Excepting a short paper of Silinich, the data of the expedition have neither been processed nor published as yet. In 1929 the geologist, B. M. Kupletsky, visited the region of the Kanda River, Vadozero and Kimetundra (cf. Trudy Petrograf. Inst. Akad. Nauk, No. 2, 1932, p. 73). Thus, from the data cited it can be seen that only N. G. Kassin (from a geological viewpoint), B. Rippas and N. Kudryavtsev specifically studied the Niva River basin. However, their investigations covered only a narrow strip along the railroad line and the Niva Riva.[3]

AREA OF INVESTIGATION

From a geographic viewpoint, the entire region under investigation is divided into a series of three individual districts.

Imandra Region

This region, extending from the shores of Babinskaya and Iokostrovskaya Imandra to the latitude of Pinozero, is characterized by considerable dissection and strong relief. The most western parts of this area attain absolute elevations of 350 to 400 m (Peschanaya, Kozhanaya, Yerma-tundra), rising above the tree line. Elevations decrease to the southeast, and attain 200 to 250 m on the Niva's left bank. Vast swampy areas with numerous lakes and small water courses are found here between isolated elevations and hills. This district is prevailingly composed of gneiss, garnet schists and amphibolites. Alluvium covering the bedrock is, as a rule, thin, consisting of bedded lake sands near the base, and in the upper parts of moraine. Near the mouth of the Niva into the Pinozero there is a high moraine ridge (up to 25 m relative elevation) representing the southern boundary of the region. Magnificent pine forests, occasionally thinned by cuttings or fires, are characteristic of the vegetation of this district.

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[3] "Ocherk issledovaniy rayona oz. Imandra" (Outline of Research in the Imandra Lake Region) in Raboty Murman. biologich. stantsii, no. 2, 1926, and in a paper by A. Polkanov, "Geologicheskiye issledovaniya na Kol'skom polnostrove v 1917-1927 gg." (Geological Research on the Kola Peninsula) in Doklady i soobshch. Murman. obshch. krayevedeniya, no. 2, 1928.

Pinozero Region

This region extends south of the Imandra region from northwest to southeast, and sharply differs from it. Among immense swamps with numerous lakes and water courses, low hills of eroded gneisses are encountered here and there, some covered by stratified lake deposits. The largest lake of this district is Pinozero, 12 km long and 1 km wide; it stretches in the same southeastern direction and is part of the Niva River system. Small areas of mixed forest are almost completely destroyed by cutting. Draining of the immense and grassy swamps could yield vast meadow land areas. To the north, as well as to the south, the district is bounded by a high moraine ridge adjoining high rocky hills called "varaki" [Knob-and-kettle topography].

Kandalaksha Region

This area is very similar to the Imandra region, though in contrast with the first area, its highest elevations are in the east. West of the Niva River the region consists of a succession of relatively low, wooded hills (up to 200 m high) with swamps and lakes in between. The rocks of this region consist mainly of gneiss, granite-gneiss and amphibolite. About 2 or 3 km east of the Niva River a mountain chain of considerable elevation begins which, in general, follows the Kandalaksha Gulf coast. Sizeable N-S and E-W depressions divide this chain into a series of small mountain ranges, i. e., the Kandalaksha mountains (Zheleznaya, Volostnaya, Srednyaya, Krestovaya with elevations of as much as 600 m; Plësova tundra is roughly 500 m high; Kurtyazhnyye, 660 m; Luvengskiye, Iolgi, etc.). Most of these elevations consist of garnet amphibolite gneiss and schists, the garnets in some places occurring in large amounts. All of these massifs are characterized by eroded rounded tops and monotonous shapes. On the southern slopes of the mountains, to elevations of 100 to 110 m, numerous shore formations are encountered (ridges, terrace-like shoulders, etc.). In the Niva valley, up to 100 to 110 m, we also encountered terraces composed of fine sand with interbedded clays covered by coarse sand and gravel upon which rests an uneroded moraine. Drill cores from the moraine ridges downstream of Pinozero lead us to assume that here, too, the moraine is deposited on stratified gravel and, in turn, underlain by an older moraine. Vegetation of the district has a sharply expressed vertically zonality. The pine and fir forest have been heavily damaged by fires and cutting; they extend to elevations of nearly 350 m, where beyond a narrow belt of subalpine birch groves, they are replaced by mountainous tundra phytocytes.

RELIEF AND STRUCTURE OF THE NIVA RIVER VALLEY[4]

The Niva River flows out of the large Lake Imandra (area: 880 square kilometers), and discharges into the Kandalaksha Gulf near the town of Kandalaksha. The position of the Niva River is determined by the following astronomic points:

	N. latitude	E. longitude of Greenwich
Source (Zasheyek village)	67°28'20"	32°32'35"
(Zasheyek station)	67°23'34"	32°35'33"
Mouth (Kandalaksha-church)	67° 7'43"	32°26'11"
(Kandalaksha-station)	67° 9'35.2"	32°25' 9.2"

For 32.5 km of its course the Niva River drops 126.83 m (according to Energostroy's data of 1930), which yields an average of 3.6 m per 1 km. However, the Niva's course is quite irregular (fig. 1). It flows through two lakes

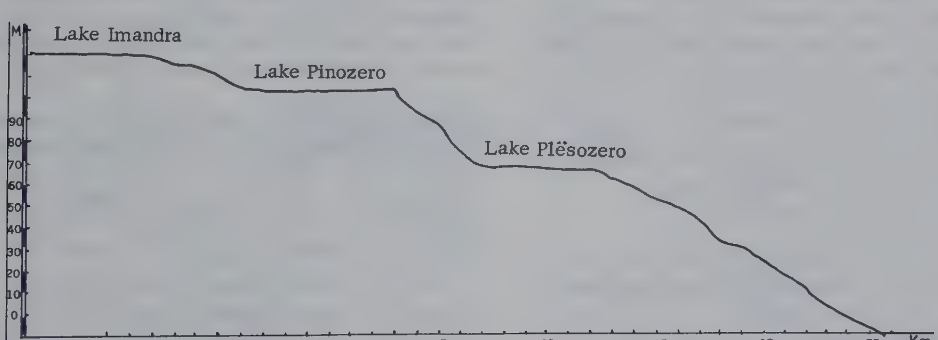

FIGURE 1. Schematic longitudinal profile of the Niva River

[4] Written in collaboration with M.K. Karpun.

viz., Pinozero and Plësozero for an overall distance of 10 km; thus, except for these two horizontal areas, the gradient is determined in terms of 5 m per 1 km. In addition to the above lakes, the river has several calmer current districts ("plësy" -- stretches of water) which are alternated by turbulent rapids (Telegrafnyy, Pinozersky, Razboynik, Yuryev, etc.). In these areas of rapids the river has a strong gradient: thus, for example, in the area of the Razboynik rapids, over a stretch of 180 m the drop is 4 m, while downstream, in the "plës" district, the drop over 240 m is only 11 cm.

Thus, we can see that the entire course of the Niva is quite irregular; it has a series of separate sections with their own bases of erosion (Pinozero, Kandalaksha Gulf) which determine the work and life of the river. The undeveloped bed and rectilinear pattern are evidence of the comparatively youthful age of the river.

Excepting the lakes, the Niva attains its maximum width in the upper part of its course. Near the source its width reaches 250 m, and slightly further down even 350 m with a depth of 2 to 3 m. A considerable narrowing (up to 100 m with depths of 4 to 6 m) takes place near the inlet to Lake Pinozero. Below there to the estuary its width ranges between 100 to 150 m, narrowing down in some places to 25 m. Maximum narrowing takes place near the Yuryev rapids (30 m) and at the outlet from Lake Pinozero (25 m). The greatest depths are attained in the "plës" districts (for example, between the Razboynik and Yuryev rapids the depth exceeds 8 m), while in the rapids the water is so shallow that all the rocks on the bottom emerge on the surface. The strong drop of the river and the emerging rocks make through navigation impossible, and render difficult the floating of timber.

Especially in the middle and lower course, the river valley is well developed, while in other parts (near the source) it is faintly pronounced; this is evidence that it developed at various time and because of varying origins in separate sections. This induces us to divide the valley into a number of morphologically distinct sections whose detailed characterization will be given below. In all, eight morphological sections have been outlined:
1) from the source to Pinozero rapids;
2) the canyon at Pinozero rapids;
3) Pinozero depression;
4) the canyon at Razboynik rapids;
5) the wide bench-shaped valley downstream of the Yuryev rapids;
6) the Plësozero valley;
7) the Plësozero canyon, and
8) the river's lower course.

The distribution of the sections is shown in the attached diagram (fig. 2) The direction of the various sections of the valley was found to follow the following succession: excepting the first section where the river makes a slight curve to the northwest, the overall direction of the valley to the southern end of Lake Plësozero is southwest. The Pinozero valley runs in a southeasterly direction. In the eighth section the river flows in a southeasterly direction (like Lake Pinozero), whereas in the lowest section it again follows almost exactly the main south-southwesterly direction.

Section 1: Outlet of the Niva River from Lake Imandra

The entire section consists of a slightly hilly lowland rising both to the west and to the east. West of the outlet the wooded elevations begin at 1.5 to 2 km from the river and form several ridges of fairly considerable relief alternated by vast swamps. In the east the forest-covered hills also rise about 2 km from the river and rapidly attain 200 to 250 m in absolute elevation.

We begin the description from the right bank. Immediately next to the Zasheyek settlement along the southern shore of Lake Imandra, a plateau of low elevation extends in the direction of the Niva outlet. Starting at a small lake 1.5 km west of the settlement with steep rocky slopes, this plateau, which consists of gray biotite gneiss with a strike of 27° NW and a dip to the SW of 17° (sample 10)[5], slopes very gently in the direction of Zasheyek. On this flat slope there are commonly found smooth outcrops of these gneisses. The spurs of this low ridge sloping down further to the east apparently form the rapids at the outlet of Lake Imandra. Only within the boundaries of the settlement are the original gneiss outcrops covered by alluvium whose thickness increases to the east. This alluvium, which consists for the most part of rounded pebbles and course detritus, commonly forms small ridges 2 to 3 m high, which, as a rule, parallel the shore of the lake. The structure of this alluvium is revealed in small pits left over from the railroad construction, and cuts on the way between the station and the settlement of Zasheyek.

Outcrop 2. In a small pit near the graveyard (outcrop 2) fine, friable, bedded sands outcrop at a depth of 1.5 m.

Outcrop 6. In a trench near the road to the settlement (outcrop 6) about 5 to 6 m above the lake the following section was found:

0 to 70 cm - Brownish-yellow, solidly cemented, boulder-pebble materials.

70 to 120 cm - Thin-bedded sand, solidly

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[5]All petrographic determinations by B.M. Kupletsky.

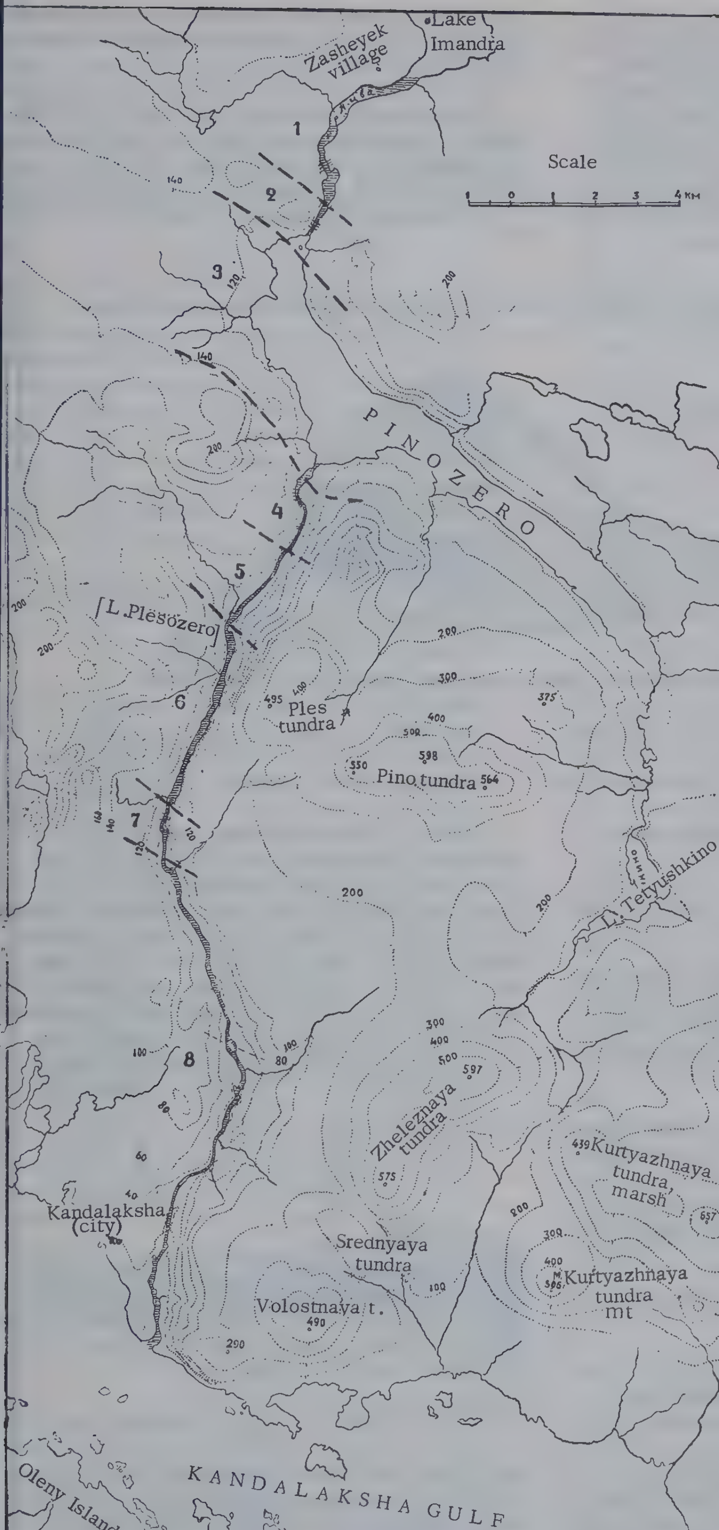


FIGURE 2. Outline of morphological divisions of the Niva River. Prepared by G.D. Rikhter, based on a map by A. I. Filippov.

cemented in the upper part by dark coffee-colored ferric oxides, becoming lighter and more friable at lower levels.

Somewhat farther on the road to Zasheyek station the first level disappears and solidly cemented, brown, stratified sand outcrops.

Outcrop 5. Slightly to the east, in the area of the railroad branch to the quay, a shallow ditch reveals the following outcrops:

Horizon 1: 0 to 7 cm - Bedded gray, fine quartz sands with roughly rolled small pebbles.

Horizon 2: 7 to 37 cm - Ocher-colored, stratified coarse sand with pebbles and grit (0.5 to 1 cm in diameter).

Horizon 3: 37 to 100 cm - Dense clay-sand with small pebbles.

The region between the settlement and the station is a plain with some swamps. A large number of boulders commonly attaining 1.5 to 2 m in diameter are found everywhere on its surface, and only in the swampy areas are they hidden under peat and moss. Individual hills or ridges consisting for the most part of boulder sand are encountered in the middle of the plain. A certain pattern of the material distribution can be determined from the small pits scattered all over the plain, namely, fine bedded sand is mainly encountered in depressions, while the positive areas of relief are composed of coarser material with more large boulders. Near the Zasheyek station proper on the slope of a small hill is a railroad pit which at present [1932] is being extensively exploited. The freshly cut and cleaned walls give a good profile of the layers constituting the hill.

The entire outcrop represents a succession of irregularly stratified sands of varying coarseness ranging from

fine-to-coarse silt with boulders and gravel; large lentil-shaped conglomerates with numerous boulders occur there. The character of the stratification can be seen from the pit cross-section shown in Figure 3. More detailed information of the stratification can be acquired from one of the outcrops (no. 2) which will be described below. This section is located almost in the center of the pit and is quite typical of the entire outcrop.

An outcropping with similar deposits is found somewhat closer to the station at the railroad club (figs. 4 and 5).

In pits near the railroad barracks where the highway crosses the railroad line, there are gray argillaceous soil outcrops. The clay particles washed out by water are deposited at the bottom of the pit where they form a clayey film.

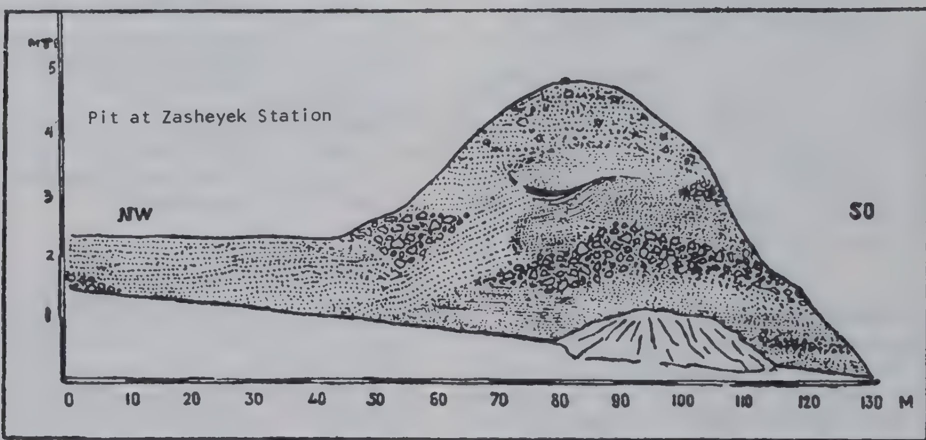


FIGURE 3. Cross-section of a hill at Zasheyek station (pit)

Outcrop No. 2 inside the railroad pit near Zasheyek station:

6 to 60 cm - Indistinctly bedded pebble-sands of a very dark brown color.

60 to 125 cm - Horizontally bedded, yellowish-gray sands with thin beds of fine gravel. The largest streaks are found at depths of 70 to 75, 90 to 100, 115 to 125 cm, occasional conglomerates.

125 to 170 cm - Thin horizontally bedded sands, slightly argillaceous, coarser in the upper parts.

170 to 175 cm - Thin beds of gray argillaceous sand, moist, sharply separated from upper and lower horizons.

175 to 200 cm - Thin gravel beds outcropping to the south.

200 to 260 cm - Gray, fine-bedded sands, the layers dipping north. Coarser grained light streaks alternating with darker and finer sands.

260 to 325 cm - Slightly bedded, friable, coarse conglomerate with large boulders reaching 50 cm in diameter, outcropping to the north.

335 to 400 cm - Thin, homogeneous, gray, stratified sand.

Further to the south no outcrops are encountered either along the railroad line or the Niva River. The area maintains its slightly undulating character with vast peat bogs covered by dwarf pines, in the middle of which isolated slightly higher, boulder ridges and hills rise here and there. Bedrock gneiss was not encountered in this area, but the great prepondance of gray gneiss boulders and their rough shape are evidence that here the gneisses must be close to the surface. The low, swampy right

FIGURE 4. General view of outcrop near railroad club

bank of the Niva River gradually rises toward the west and forms beyond the railroad line a wide, mostly dry terrace 130 m high; it also forms a second terrace 138 m high which is as clearly outlined as the first.

In the area under investigation, the left bank

of the river has the same character as the right. The Niva, hardly cutting its way into the soil, does not cut a valley here and flows over a swampy plain. No outcrops have been found on the left bank. In order to investigate the structure of the bottom of the left bank, the members of the expedition, M.K. Karpun and I. V. Maksimov, explored along the railroad line to the Niva cut and studied the Niva pit. The data of this exploration are given below.

Let us now examine the Niva pits. The entire region between Zasheyek station and the Niva cut is a flat lowland rising but slightly above the level of Lake Imandra. The flat depressions represent vast boggy areas covered with moisture-loving grasses and shrubs; they are drained by brooks flowing into Lake Imandra. Flat, oval hills a few meters high rise above the swamps here and there; their surface is entirely covered with boulders and overgrown with xerophytic plants. The Niva railroad station stands on one of those hills.

Outcropping at 1210 km. - This is in a hollow on the slope of the hill on which the railroad building is located. Amidst flat lowlands overgrown with bog pines there rises a sloping hill of low elevation but considerable area. All over its surface gneiss boulders are scattered. In the upper part of the section is a soil layer with a well-developed ortstein [hardpan] horizon. It is underlain by gray sands with a low boulder content. In the sand are noticeable poorly expressed whitish-yellow, slightly argillaceous horizontal bands. In the gray sand mass are accumulations of completely decayed mica gneiss. Further down the moisture content of the sand increases, resulting from a somewhat greater admixture of clay. Visible thickness of the sand is 85 cm.

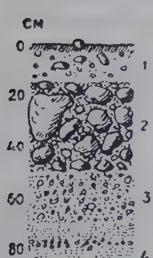


FIGURE 5. Detail of the columnar section near the railroad club

Outcropping at 1211. 2 km. The railroad pit cuts into the top of the same hill containing the hollow described a above. The pit is a large basin containing a small lake. Apparently this lake is permanent because inside and around it a specific flora and fauna has developed, including tadpoles and small fish. A brook flows out of the small lake in the direction of Lake Imandra. Ground water emerges from the base of the pit walls, and at one place a spring jets from the ground. On the lake bottom are deposits of blue and yellow clay. The section begins with a solid layer of gravel and shingle 40 cm thick. From the surface traces of erosion are evident, so that it can be assumed that it was originally considerably thicker. The layer is horizontal. Contact with the next layer is sharply outlined, the conglomerate commonly wedging into it without upsetting its structure. The conglomerate lies unconformably on dark-brown sand interbedded with gravel and fine conglomerate. The sandy bands are solidly cemented by ferric oxides; with erosion of the layer they appear scaly (Figure 6: Photo. Cross-section of lower pits at 1211 km railroad point). This ortstein horizon is separated from the alluvial horizon by a layer of a permeable conglomerate. The stratum, 1 meter thick, is cross-bedded and sharply delimited at the bottom. The layers dip 227°SW at an angle of 20° and to 205° SW at an angle of 18°. The third layer is continuous and uniform, and it consists of fine horizontally bedded sand containing considerable black mica and some clay. The bottom layer is water-bearing.

The next pit is cut into the slope of the hill, only its upper horizons being exposed. Examining the cross-section, there is from the top a cross-bedded sand layer, like the one encountered previously, yet its structure is not as clearly defined. The deposition and cross-bedding of the layers with one another is noticeable, however. The thickness is 60 cm. The sand gradually turns into a level of gravel and fine conglomerate; further on, gravel layers alternate with layers of arkosic sand. In this layer, also 60 cm thick, there is from the top an oblique stratification which below becomes horizontal. The next layers directly beneath the gravel consist of light-gray sand with a noticeable fractional cleavage. In its lower part the above layer has a slightly wavy cleavage which above becomes more distinct and at the top turns into perfectly defined ripple marks. The thickness is 1. 8 m. Beneath it there is again a water-bearing layer of gravel up to 2m thick.

Like the right bank, the left one also gently rises from the river toward the southeast, and only at an absolute elevation of 130 m does it have a steeper slope. The area beyond it rises rapidly, the mixed forest of firs and birches is replaced by pines which cover the slopes and tops of the hills. The southern hills are close to the river and make a steeper slope on the plain.

As mentioned previously, in its upper course the Niva is not expressed by a clearly defined valley. It flows smoothly over the rapids at the outlet located at an elevation of 124. 75 m, and further on approaches the railroad bridge as a wide, fairly rapid and roaring torrent. Its bottom is covered with large boulders and blocks which emerge from the water across the entire width of the river. At the outlet the river is 450 m wide, but it gradually narrows and below

TABLE 1. Data of mechanical analysis of samples from drill hole No. 2

Characteristics of rock	Number of samples	Depth of sample extraction in mm	Fraction of mechanical analysis in percent of weight										
			>20 mm	20 - 7	7 - 5	5 - 3	3 - 2	2 - 1	1. - 0.5	0.5-0.25	0.25-0.05	0.05-0.01	<0.01
Soil horizons	3	0.23	-	19.41	3.90	6.31	4.53	13.59	8.78	12.01	23.25	4.52	3.10
	5	0.48	-	12.08	3.11	4.12	3.20	7.23	6.50	11.24	32.85	11.41	8.25
Gray clayey sand moraine with gravel and large quantities of large angular boulders without traces of bedding but with individual lenses of clayey soil	6	0.84	12.69	9.20	1.34	3.08	3.04	6.86	6.23	9.58	30.18	11.02	6.86
	8	1.42	12.22	9.89	1.89	2.48	2.21	11.10	4.67	9.18	26.49	7.98	11.89
	9	2.50	12.92	5.52	2.14	3.29	2.80	5.72	6.76	10.98	30.60	9.80	9.47
	9b	4.20	-	7.89	2.14	3.62	2.66	8.29	6.41	11.12	36.65	9.99	10.93
	9d	7.30	19.48	6.02	4.38	3.46	2.88	6.66	3.43	4.43	27.70	8.85	12.71
	9zh	9.00	-	8.42	1.83	3.49	3.12	8.20	6.00	7.50	39.15	11.05	11.24
	10	9.16	-	10.64	2.21	4.61	4.85	14.61	4.88	8.85	25.23	9.46	14.66
	11	9.40	-	13.39	2.41	2.91	2.28	4.40	19.26	15.02	17.14	4.54	18.65
	13	11.20	-	12.00	2.60	5.29	3.53	9.92	8.12	8.61	34.35	8.84	6.74
	14	13.00	-	9.25	2.03	3.59	2.86	7.80	8.95	9.49	23.27	10.80	21.37
Bedded sands with gravel and boulders	15a	15.30	-	17.77	1.93	3.48	2.65	5.95	6.12	9.05	25.48	22.80	4.77
	16	15.60	-	1.09	1.04	2.78	3.05	13.51	18.45	21.37	31.35	6.48	0.87
	16a	15.80	-	25.02	3.38	5.51	4.00	12.26	13.78	14.97	18.77	1.84	0.47
	16b	16.73	-	38.75	4.06	7.17	4.46	10.02	6.41	9.82	18.60	0.61	0.10

the railroad bridge is only 175 m wide. After that it widens again reaching 350 m in width and forms a calmer and deeper "plёso" stretch of water. Two small brooks which flow in the opposite direction of the Niva and almost completely dry out in the summer flow into it from the right side at the beginning of this "plёso". Further downstream the river again narrows to 110 m at the Telegrafnyy rapids which empty into the second wide "plёso" (Figure 7: Photo. Second "plёso" of the Niva; background, Telegrafnyy rapids). Here the hills approach the river from east and west making the valley less wide, thus forming a sharp morphologic boundary.

Summing up the observations of the Niva's upper course we find the following morphologic features:

1) The entire area is a flat, slightly hilly, occasionally swampy lowland, rising towards the adjoining elevations at first gently to an elevation of 130 m, and thereafter rather steeply.

2) Amidst this plain are isolated low hills and ridges, consisting mostly of large boulders.

3) The wide Niva River forming a series of widenings which alternate with narrow sections of rapids has no distinctly defined valley.

4) Bedrock gneiss was found only near the outlet of the lake, elsewhere it is covered to various depths by alluvium.

5) All of the exposures of the alluvium bear evidence that it is water-lain; its irregular cross-bedding, and the variation in coarseness indicate that deposition was near the banks from running water (deposits of the delta or sand-gravel type).

6) Well-defined terraces at 130 and 180 m, and sharp change in the slope at these levels indicates that, up to that height, the entire area was covered by water from a shallow stagnant basin.

Section 2. Canyon at Pinozero Rapids

Four kilometers from the outlet the topography of the region as well as the nature of the flow of the Niva changes abruptly. A high, flat-topped hill (absolute elevation 154 m) rises directly from the river on the right bank; this hill is part of a high moraine ridge trending in a southeasterly direction. (Figure 8. Photo. Edge of moraine ridge on right bank of Niva near Pinozero rapids). Here and there this ridge is eroded and at present represents a series of isolated hills. The left bank also descends abruptly to the river forming a steep slope 23 m high. Further along the bank, the area rises even higher to elevations of 200 m above sea level.

Cutting through a high ridge, the Niva narrows to 100 m and forms a canyon-like valley with a terraced left bank (Figure 9: Photo. Niva River valley from right bank along axis of planned dam at Pinozero rapids).

The slope of the valley along the right bank has only one 6 m high terrace distinctly defined, while the slope of the hill facing south has several clearly defined terraces rising to an absolute elevation of 120 m.

The geological structure of the region becomes apparent from samples extracted from drill cores (cf. the attached profiles with mechanical analyses).

Test holes in the higher parts of the right bank disclose a fairly uniform composition of the sand moraine with a large number of boulders lying on bedded, cleanly washed sand and gravel. For the characterization of the deposits mentioned above, the results of the mechancial analysis of samples from test hole No. 2 on the right bank of the Niva, obtained by Ye. A. Gromovaya at Energostroy laboratories, is given below. The hole was bored into the slope of a hill near the edge of the valley at an elevation of 135. 7 m above sea level (table 1).

As is seen from the analysis data given in Table 1, the moraine formation is characterized by a surprising uniformity of the texture, which is much more varied in the underlying sand with shingle, a sharp decrease in clayey and dustlike particles being characteristic for these.

The bottom boundary of the moraine lies at an absolute elevation of 119 to 120 m. Drill holes at water level show a regular alternation of sand layers from thin clayey, through medium and coarse-grained, to gravel layers, forming four-deposit formations one above the other to a depth of 13 m (100 m absolute elevation). Rock samples from test hole No. 2 yielded the results shown in Table 2.

In addition those indicated in Table 2, on the moraine surface and in the river bed the following boulders were found: metamorphosed gabbro, garnet gneiss, ferrous quartzite.

For the characterization of alluvium of this area we refer to results of the analysis of samples from test hole No. 4 on the Niva's right bank (table 3).

As is seen from the comparison of the results of this analysis to those given in Table 1 the mechanical composition of the moraine is almost identical.

As is seen from Table 2, the bulk of boulders is composed of local gneisses. Worth noting here is the segregation of quartzite boulders in

TABLE 3. Data of mechanical analysis of samples from Drill hole No. 4.

Characteristics of rock	Number of samples	Depth of sample extraction in mm	Fractions of mechanical analysis in percent of weight										
			>20 mm	20 - 7	7 - 5	5 - 3	3 - 2	2 - 1	1 - 0.5	0.5-0.25	0.25-0.05	0.05-0.01	<0.01
Soil horizons	2	0.02	25.21	13.70	4.81	11.07	7.08	10.13	5.67	3.01	14.28	3.29	1.75
	3	0.17	-	10.02	3.95	6.68	5.01	9.49	4.54	5.67	20.16	15.40	19.13
	4	0.42	-	18.92	2.77	4.28	3.32	6.81	5.75	11.82	27.80	11.02	7.51
Light-gray homogeneous argillaceous sand moraine with large numbers of boulders and gravel	6	1.29	-	11.94	2.12	4.18	3.54	7.19	7.81	9.77	32.15	10.65	10.65
	7	1.82	7.87	3.95	1.99	3.57	2.65	6.75	6.41	10.98	36.42	9.16	10.25
	8	2.75	9.23	7.10	2.17	3.10	3.01	6.91	7.53	9.42	34.07	8.39	9.07
	9	3.90	-	5.94	2.64	4.28	3.70	8.41	7.31	7.69	36.96	13.32	9.75
	10[a]	5.90	-	-	-	2.00	2.75	9.00	12.75	15.75	40.25	8.50	9.00
	11	6.90	-	11.04	2.62	3.93	2.98	8.46	5.68	10.64	32.65	12.78	9.22
Bedded sands with gravel	12	12.20	-	3.32	0.47	0.70	2.75	15.01	10.88	16.89	39.43	6.22	4.27
	17	15.87	-	14.74	7.77	12.47	4.90	9.11	7.05	19.09	11.37	7.57	5.33
	20	17.46	-	16.44	5.23	9.72	6.80	12.10	10.28	23.36	9.68	4.06	2.33
	22	18.67	-	17.33	2.94	6.11	5.72	9.68	6.84	17.91	18.49	8.12	6.86
	23	19.04	-	6.29	2.26	5.41	5.44	10.42	10.63	30.37	17.70	7.64	3.79

the moraine on the northern shore of Lake Pinozero near the estuary of Shiroky brook.

Table 2.

Depth in meters	Determination
0	Micaceous granite-gneiss
0.85	Amphibolite
0.95	Granite with epidote
1.70	Biotite gneiss, garnet-hornblende gneiss
4.50	Micaceous gneiss, amphibolite
4.70	Micaceous gneiss
5.30	Micaceous gneiss aplite vein
5.40	Muscovite granite (plagioclase)
-	Micaceous gneiss with pegmatite vein
6.20	Biotite gneiss, epidotized granite
6.25	Muscovite granite
6.30	Quartz and feldspar
6.40	Pegmatite
6.50	Epidotized granite with epidote streaks
6.80	Hornblende gneiss with feldspar amphibolite
7.00	Quartz-orthoclase gneiss
7.30	Quartz
8.20	Pegmatite
8.50	Hornblende gneiss (metamorphosed gabbro)
8.60	Actinolite shale
9.00	Orthoclase porphyry
9.10	Hornblende gneiss and gangue (?)
9.15	Medium-grained hornblende gneiss, feldspar amphibolite with garnet, hornblende with epidote, fine-grained micaceous gneiss
9.20	Biotite gneiss, fine-grained
9.25	Quartz
9.30	Gangue (?)
9.40	Quartz with feldspar
9.50	Gneiss
10.00	Quartz
11.00	Hornblende gneiss
12.00	Gangue (?)
13.00	Biotite gneiss
13.20	Biotite gneiss. Hornblende gneiss.
13.65	Epidote gneiss
14.40	Diabase
14.80	Chlorite-hornblende shale.

The opposite (left) river bank has an entirely different structure. Over the entire length of the Pinozero rapids native gray gneiss outcrops penetrated with pegmatite veins were found only in three places from water level to a height of 10 m. Similar outcrops were discovered, however, higher up on the slope and near the top of the high hills on the left bank. (Figure 10: Photo. Gneiss bedrock on the left bank of the Niva near Pinozero rapids.) The intervals between these outcrops are covered with a moraine of the same type. The same material covers the outcrops on the tops of nearby hills, as can be seen from data of test hole No. 4 (table 3 and description of drill hole 4). Considerably higher, at an absolute elevation of about 190 m east of the valley we discovered a well-defined terrace which slopes fairly steeply into the adjoining swamps. The structure and genesis of this terrace remained unexplored, but the coincidence of the marks of this terrace with the upper boundary of the washed deposits noticed by Ramsay on the Syraya tundra and at Kuzvarenche (197 m) gives us reason to believe, as he did, that the level of the Imandra reservoir was high. From the south this reservoir was fed by a glacial stream.

The small thickness of alluvium in the river, the absence of clearly defined terraces on the valley slopes (excepting the left bank), as well as the rapid and irregular current of the river are evidence of a comparatively youthful origin of this part of the valley (Figure 11: Photo. Pinozero rapids, view from left bank).

On the basis of the entire complex of observations, the evolution of the described part of the valley is as follows. The moraine ridge which extends from northwest to southeast originally adjoined directly the rocky slopes of the hills on the left bank, and the Niva River did not exist. As the level of Lake Imandra rose, an outlet for the water was cut into the Pinozero depression which started a vigorous washout of the ridge. The terraces on the left bank and the steep slopes of the right bank without terraces are evidence that the bed of the river shifted from east to west along the contact of the moraine with the gneiss outcrops. At that time the level of Lake Pinozero was at 120 m to 130 m. After a fairly rapid drop in the level of Lake Pinozero the river cut its bed even more vigorously. This period corresponds to the formation of the terrace from large boulders at an absolute elevation of 120 m on the river's left bank. The fine moraine material was carried by the river into the lake, while the large boulders scattered on the moraine settled with the bottom of the valley inhibiting further washout. The steep slope of the right bank covered the turf and forests indicates that the process of deepening on the river bed has been considerably slowed down, and that at present the river shifts westwards.

Section 3: Pinozero Depression

Immediately beyond the moraine ridge the character of the region changes abruptly. A fairly narrow swampy depression (2 to 3 km wide) stretches northwest to southeast, its lowest part being occupied by the long narrow Lake Pinozero which extends in the same direction. West of the lake, swamps feed numerous brooks which flow into Lake Pinozero, Lake Babinskaya Imandra, and through the systems of the Savina and Lupcha rivers into Kandalaksha Gulf. In this region are no hills of any substantial size; amidst enormous swamps with occasionally scattered small lakes and marshes, low rounded hills (2 to 3 m relative elevation) are encountered now and then. These hills consist of bedrock outcrops of biotite gneiss. Near the lake shore along the railroad two narrow sinuous ridges extends for 1.5 to 2 km; they consist of boulder sand and are typical eskers. The gneisses constituting the entire district have a prevailingly a northwest strike, and dip both to the north and to the south. Except for these small hills, no other outcrops were found anywhere else in the district. The bedrock outcrops smoothly levelled from northwest to southeast, the eskers stretching in the same direction, and the absence of alluvium or its negligible thickness (excepting the lake shore proper), as well as the general features of the relief induce us to believe that this section was the channel of an arm of a large glacier which once covered the entire region under investigation and left the lateral moraine which closes the outlet of the Niva into Lake Pinozero. (Figure 12: Photo. Outlet of the Niva into Lake Pinozero).

Somewhat further south near the turn of the western Pinozero shore towards the southeast, the character of the region changes abruptly. Here we find numerous hills rising from the lake shore towards the west. On the tops and slopes of these hills there are bedrock gneiss outcrops of the lower, and garnet-shale outcrops on the higher sections. Here the alluvium is thin, so that in all the railroad excavations we could see bedrock. Such outcrops were marked at 1190.2, 1192.6, 1193 and 1195 km from Leningrad. They consist for the most part of biotite gneisses, occasionally turning into granite-gneiss with individual intercalations and lenses of amphibolite gneiss and numerous aplite and quartz veins cutting them generally along the strike. These gneisses are fairly strongly thrust into small plunging folds; occasionally, however, the folding is so weak that it only reaches the plication stage. The southern part of the described section should be regarded as the southern tip of the channel of the Pinozero glacier stream. In addition to the outcrops in the railroad excavations, bedrock outcrops were also found on the hills west of the railroad line, as well as along the shores of Lake Pinozero and the Niva banks near the outlet. The shores of Lake Pinozero have, on the whole, the same character of the hilly lowland rising to the north and to the south. At some points of the shore we found gneiss outcrops with an almost due east-west strike. In the upper parts of the shore the bedrock outcrops are covered by unwashed, thin, moraine alluvium, while below the 120 m mark they are covered by lake bed deposits in the form of sands or clays. Wide lake terraces emerge on the southern and western shores of Lake Pinozero at 120 m, 117 m, and 114 m, while at higher elevations they are less clearly-defined, although they are detectable up to an elevation of 230 m. The structure of the lake deposit can be seen from the description of excavations, pits and drillholes given below.

Outcrop at 1191.4 km of railroad line. Near the railroad bridge crossing a brook near Pinozero station, in a small flat hill a few pits were dug out from the spots where the local inhabitants extract clay for the construction of hearths and stoves. Clearing of one of these pits gives the following section:

0 to 33 cm - Soil layer 10 to 15 cm thick on gravel sand, below that rusty-brown, thinly bedded sand.

33 to 44 cm - Greenish-gray, fine clayey sand with bands of sand.

44 to 114 cm - Greenish-gray bituminous clay, drier on the top, moist and plastic at the bottom. Occasionally the clay contains boulders and slightly rounded fragments of eroded gneiss.

114 to 140 cm - Alternating sandy and clayey stratifications with highly eroded boulders.

In the brook valley the deposit of gravel and sand is eroded and the clay outcrops directly on the surface. Mechanical analyses of clays effected at the LOE laboratory yielded the following results. Similar clays were discovered in digging a well in the courtyard of a house of Pinozero settlement, at a depth of approximately 80 cm under a layer of stratified clayey boulder sands. Shallow pits and excavations at other spots of the settlement (at the Zhelles office and elsewhere) disclose, to a depth of 50 to 70 cm, coarse-grained stratified

Fractions in meters	Sample No. 132	Sample No. 860
	in percent of weight	
2 - 1	-	0.25
1 - 0.5	traces	0.25
0.5 - 0.25	0.25	0.25
0.25 - 0.05	4.25	1.50
0.05 - 0.01	11.50	10.75
Particles <0.01	84.00	87.00

sand with gravel and individual boulders and bands of fine clayey gray sand, the latter prevailing in the bottom parts of the profiles. Here the area is a slope, most of which is swampy, slanting toward the lake with low and gradual ridges stretching to the southeast. The presence of swamps in the region is explained by the clay base, as well as by the crystalline basement being close to the surface. Gneiss was discovered in a drainage canal in the center of the swamp south of Pinozero settlement, immediately beneath a 50 cm peat layer. West of Pinozero settlement, at a distance of approximately 1 km, on the northern slope of a wooded hill (point 49) we discovered outcrops of clearly stratified light-gray biotite gneiss with a strike 135° SE and a low-angle dip to southeast. The gneiss contains a narrow pegmatite vein.

Beyond the turbulent outlet from Lake Pinozero, which is not wider than 50 m, the Niva forms a calmer stretch of water with flat rocky banks. The rocks (gneiss) are mostly angular or slightly rounded, only a few being well-rounded (Figure 13: Photo. The Niva at the first "plëso" below Lake Pinozero Angular blocks of gneiss in foreground, moraine ridge near Razboynik rapids in background). The intervals between rocks are filled by contemporary silty-sandy alluvium. Bedrock outcrops frequently appear among the rocks on the banks. They take the form of highly polished rocks of biotite gneiss and granite-gneiss. Many of these outcrops cover such small areas that they may be taken easily for large boulders; yet, the fact that their occurrence is identical with that of larger outcrops leaves no doubt that they are bedrock.

<u>Outcrop at point No. 81 on the right bank of the Niva River.</u> One of the large outcrops is found at the very beginning of the first stretch of water in an area flooded by the river in the spring. The outcrops are highly polished and they appear in the form of flagstones 9 m long and 3 m wide. Since the gneiss in this outcrop (sample 161) is strongly contorted into small folds, it was possible to determine only the prevailing strike which was found to be nearly east-west (270°) with a 87° dip to the south. In other parts of the outcrop the strikes are somewhat different, reflecting two small folds.

<u>Outcrop at point No. 80 at the same spot.</u> 200 m downstream there is another outcrop of the same gneiss, but somewhat richer in biotite, with small quartz and aplite veins and stocks; it is also contorted into small folds and has an almost horizontal strike.

Further south to the mouth of a small brook and the end of the "plëso" all shorelines are covered with angular blocks which doubtlessly are in situ. The above two outcrops occur at the foot of a very low and flat ridge which rises gently towards the railroad line.

<u>Outcrop in railroad excavation at 1190. 7 km.</u> At the intersection of this ridge with the railroad line (point 17) there are outcrops of strongly metamorphosed, coarsely bedded hornblende gneiss with black amphibolite streaks alternating with pink zones of granite gneiss with a 40° NE strike and a northwest dip; these outcrops are covered with greenish-gray unstratified clay loam. South of the ridge there is a narrow swamp crossed by a brook. Near the road from the settlement to the Energostroy camp at Razboynik rapids, 5 m from the brook we manually bored a test hole into the swamp near the Niva which yielded the following results:

0 to 110 cm - Fibrous peat, poorly decomposed (sample 855).

110 to 130 cm - Silty layer of chocolate-colored particles of decomposed peat (sample 856).

130 to 245 cm - Grayish loam with sand lenses (samples 857, 858).

245 to 263 cm - Gray sand with gravel, compacted (sample 859).

<u>Outcrop of point No. 14 on the right bank of the Niva.</u> South of the small swamp, in the west-northwest direction from the Niva bank a second, more distinctly defined though flat ridge runs parallel with the ridge described above. Polished outcrops of granite-gneiss which constitutes this ridge are encountered from the river bank along its entire stretch; they are barely covered with sod 10 to 20 cm thick. At the intersection point of this ridge with a path, where the sod is decayed, there are outcrops of metamorphic biotite gneiss striking 45° NE dipping to the northwest. The same biotite gneiss (sample 28) outcrops at several places under a slightly upheaved sod layer. Excavation at this ridge yielded the following profile (point 82).

<u>Outcrop at 1190. 2 km of railroad line:</u>

0 to 60 cm - Yellowish-brown, slightly-bedded, faintly clayey sand with large quantities of boulders and gravel.

60 to 190 cm - Greenish-gray fine sand, slightly stratified at the top, but not below. Large quantities of highly eroded granite-gneiss, gneiss and micaceous shale boulders.

190 cm and lower - Variegated gneiss with a strike of 320° NW and a northeast dip of 11°. The gneiss is cut by aplite veins with a thickness up to 10 cm which parallel the stratification.

<u>Outcrop at point No. 83.</u> West of the excavation the ridge rises higher; behind the graveyard a small hill rises on its surface, whose slopes and top are almost bare of alluvium. On the

top and slopes there are gneiss outcrops (occasionally disrupted into small folds) with a strike of 110° SE and a northwest dip of 52°.

No bedrock outcrops were discovered further west.

South of the above ridge there is a swampy depression crossed by a small brook. No outcrops were found in this area, and only at the river bank and in the bed of the brook near its mouth angular edged gneiss blocks and slabs indicate the nearby occurrence of bedrock.

The left Niva bank from its outlet from Lake Pinozero to Razboynik rapids is a series of lake terraces attaining a width of 500 m with a comparatively small number of boulders on their surface, which sharply increases to the south opposite the beginning of the rapids. Here the boulders form ridges in between which there are narrow dry valleys which open into the river valley. A high hill forming the left bank in the area of the Razboynik rapids slopes to the river as steep cliffs and large alluvial deposits at the base.

The best defined terraces are at 120, 117 and 114 m of absolute elevation (2, 5, and 8 m of relative elevation).

The morphological features of the shores and the structure of the alluvium are positive evidence of lake Pinozero's formerly higher level (120 m) and of its intermittent drops. Although in some places there are traces of terraces at even higher levels (up to 135 m), in most cases they are not distinctly defined and cannot be followed over long distances.

Section 4: Canyon at Razboynik Rapids

Both to the north and to the south the Pinozero depression is bounded by a huge moraine ridge attaining about 20 m of relative elevation. In composition and shape the southern and northern ridges are very much alike. The southern ridge stretches from a high hill west of the outlet of the Niva from Lake Pinozero, and from the railroad line crossing the river, and joins the hill on the left bank.

Like Section 2, this moraine ridge is cut by the Niva River at the junction of the moraine and the rocky edge of the hill. By deepening its bed, the river shifts westwards. The top parts of the outcropping rocks bear clear evidence that the river once flowed there: well-eroded and polished rocks with well-rounded and polished boulders of the surface. (Figure 14. Left bank of the Niva at the Razboynik rapids. In the foreground are well-polished and eroded rocks. Beyond the narrow stretch of the river are the Yuryev rapids.)

The character of the bottom of the Niva valley also changes abruptly in this section: the entire flood plain is covered with large, well-rounded boulders of varying petrographic composition, but with a considerable predominance of gneiss (hornblende gneiss, gabbroids, amphibolites, drusites, diabase, porphyrite). The ridge slopes on the right bank are well-drained and covered with burnt-out forests; bedrock outcrops have not been found here and the structure of the ridge must be interpreted from drilling reports.

In all, 10 holes were drilled into the above ridge (fig. 15). A brief descriptions of them follows:

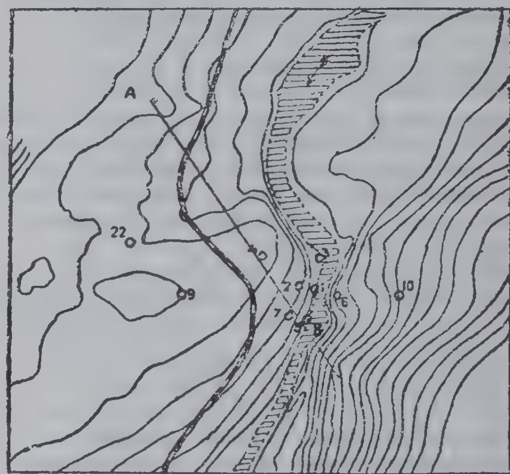


FIGURE 15, Distribution of boreholes in the area of Razboynik rapids. Line A-B indicates the direction of the profile (fig. 16)

Drill hole No. 1 is located at the edge of the valley at point 119.03 m. Under a small diluvial layer (0.32 m), consisting of mixed sand with gravel and boulders, there is a thick (up to 8.25 m), very uniform layer of sandy, slightly clayey-loam moraine with large quantities of gravel and boulders. Below, to a depth of 14.20 m, gray, coarse-grained sand alternates with gravel containing boulders and interstratifications of finer sand. By October 18 drillings in this sand reached 18.55 m. The water level in the drill hole fluctuates around 17 m from the surface (102 m of absolute elevation).

Drill hole No. 2 is located at the foot of the ridge slope at the Niva water level (mark at its mouth 103.73 m). There is a regular alternation of gray, fine-grained sand and medium or coarse-grained sand and gravel with considerable quantities of boulders and coarse gravel. By October 28 the pit attained 11.30 m. Later on, a grinding bit with a lubricating device was installed there; according to information at my disposal it appears that at a depth of approximately 50 m the formation of stratified sand and gravel was replaced by a reddish-brown clay

moraine, which was penetrated to a depth of 57 m without encountering bedrock.

Drill hole No. 3 was 120 m higher upstream from drill hole No. 2, on a small promontory in the upper part of the Razboynik rapids near the water level at the 103.53 m mark. Below a layer of boulders, where the spaces between them are filled with detritus, shingle and gravel (up to 1.20 m), the drill penetrated the same stratified boulder sand of varying coarseness as at drill hole No. 2. By October 28 these sands were drilled to a depth of 14.29 m.

Borehole No. 4 is located on the top of the ridge not far from the railroad line at 127.06 m. Diluvium roughly 1 m thick and composed of mixed sand is followed by a thick moraine similar in character to that of drill hole No. 1. From the depth of 8 m (119 m absolute elevation) the moraine is replaced by stratified sand and shingle, as at drill hole No. 1. By October 28 the hole had been dug to a depth of 20.84 m.

Borehole No. 22 is located in the depression between the top of the ridge and a high hill west of the railroad line. After penetrating the moraine to a depth of 5 m, it reached bedrock.

Drill hole No. 5 is located 120 m downstream from drill hole No. 2 at water level (103.65 m of absolute elevation). Below a thick alluvial layer, by October 22 the hole was drilled to a depth of 5.85 m into stratified sand and gravel with large quantities of boulders.

Borehole No. 7 is located at the edge of the valley above drill hole No. 5 (mark at mouth, 114.01 m). Diluvium 1.5 m thick is followed by a thick moraine similar in character to that of drill holes Nos. 1, 4, etc. At a depth of 9.20 m in the moraine is replaced by stratified sand and shingle with boulders; by October 28 the depth attained in this sand was 12.54 m.

The main features of the ridge structure are shown in the cross-section in Figure 16.

At a distance of approximately 1.5 to 2 km in a westerly direction the moraine ridge is in contact with a fairly high hill (approximately 210 m high) on whose western slope near the top there is an outcrop of biotite granite gneiss occurring in a precipice of approximately 50 m. The rock is broken into acute and an oblique jointing, the strikes of which are 335° NW dipping at an angle of 65° and 288° NW, dipping at an angle of 90°, respectively. Gneiss crops out 10 meters further down the slope. It is intruded with pegmatite veins and its overall strike is 163° SE dipping at an angle of 12°. The entire slope is covered by a blanket of moraine deposits. The slanting southwestern slope contains several planoconcave terraces and small shallow valleys. West-northwest and northeast from the elevation, steep-sloped spurs branch out, which are especially pronounced toward the northwest.

West of the hill there is a wide swampy depression from which numerous small brooks drain into the large Tente brook which flows into the Niva near the northern tip of Lake Plësozero. The lowest parts of this swamp are very likely covered with water during thaws, thus becoming a lake.

The left Niva bank has a completely different character in the investigated district. Over the entire range of the lower parts of the Razboynik and Yuryev rapids, gneiss rocks (mostly biotite gneiss) dip abruptly down to water level. These rocks have seams of amphibolite cut by pegmatite vein (Figure 17: Photo. Gneiss outcrops on the left Niva bank at Razvoynik rapids). Over the entire length of both outcrops, the gneiss occurs in several dipping folds with their axes striking southeast and dipping west. At the very beginning of the outcrop near the Razboynik rapids the gneiss contains a vein of melilite porphyry approximately 6 m thick. The bare and highly eroded and polished gneiss outcrops are still encountered at an elevation of 120 to 125 m; higher up they are covered by the moraine. The foot

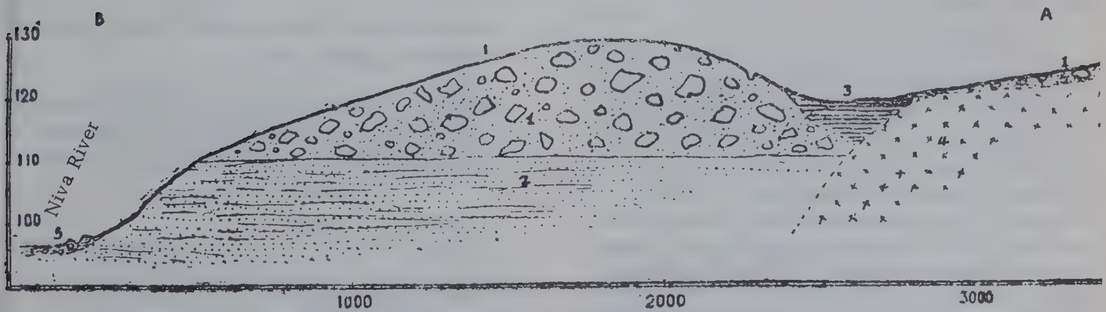


FIGURE 16. Cross section across the Niva's right bank along line A-B (cf. fig. 15)
1 - moraine. 2 - stratified sand and shingle. 3 - stratified clay. 4 - gneiss. 5 - alluvium.

of the precipice is filled with huge, angular gneiss blocks, with extensive fractures. Near the edge of the precipice at mark 119.35 m, hole No. 8 was drilled which penetrated into the biotite and hornblende gneiss to a depth of 26 m. At a depth of 1 and 4 m, the gneiss is cut by pegmatite veins.

Between the two outcrops mentioned above there is a wide ravine enclosed from the north and from the south by rocky hills. Opposite this ravine the Niva becomes somewhat wider and forms a calmer "plёso". At the bottom of the ravine, at mark 111.67 m, we drilled test-hole No. 6 and exposed a greenish-gray, slightly silty sand with gravel and occasional boulders, which farther down turns into fine quicksand. The nearness of bedrock is evidenced here by ground water occurring on the ravine bottom near the bank, as well as the presence of quicksand in the bottom part of the test hole; nevertheless, hole No. 6 did not reach bedrock by October 28 (the depth attained was 4.10 m). The features of the moraine covering the native rock outcrops at Razboynik rapids can be interpreted from the data from hole No. 10 located on the slope of a hill on the left bank at 136.78 m.

0 to 37 cm - Diluvium -- grayish-dark-blue, fine sand with well-rounded gravel and occasional angular large boulders of varying petrographic composition.

37 to 65 cm - Greenish, grayish-yellow, unstratified, slightly clayey sand with large quantities of small, well-rounded boulders and gravel.

65 to 130 cm - Gray, slightly clayey, stratified sand with large quantities of well-rounded boulders, 5 to 10 cm in diameter.

130 to 300 cm - Heavy, brownish-gray loam with overtones of green. Huge quantities of angular blocks and rubble without trace of polishing.

No bedrock was encountered higher up on the slope or on the top of the hill; apparently all of the hills on the left bank are covered by a moraine cover.

On the basis of available geomorphological and geological data, the origin of this area can be outlined as follows. A deep southwesterly striking fissure, developed by stream erosion a deep valley in the crystalline rocks, which was covered subsequently with moraine and stratified sand mixed with gravel. These stratified layers were covered by a lateral moraine of the Pinozero glacier, which closed the Niva valley and made a natural dam, behind which Lake Pinozero rose to 121 m. Once the Pinozero basin was filled with water, an outlet was established along the left shore near the 120 m mark. Well-washed and polished rocks are evidence of this. Finding resistance on the left shore in the form of crystalline rocks, the river dug its bed into the moraine piled against the edges of the cliffs. Individual protruding rocks inhibited erosion, and because of this phenomenon, the level of Lake Pinozero dropped irregularly; thus, shoreline terraces were formed. The protruding rocks at 117 to 114 m correspond to terraces at corresponding elevations. Boulders washed out from the moraine accumulated in the bed and inhibited further erosion; as a consequence, scouring of the right (moraine) bank has at the present time stopped almost completely. (Figure 18: Photo. Razboynik rapids, view from right bank.)

Section 5. Terraced Valley below Yuryev Rapids

The moraine ridge which extends from the southwest to the northeast below Yuryev rapids recedes to the west, and the entire right bank of the river is a flat ridge sloping toward the river. The right bank preserves this character to the mouth of the large Tente brook near the northern tip of Lake Plesozero. No outcrops were encountered on the right bank; 150 m from Yuryev rapids the river bank forms a rocky terrace 2 m above the river (98 m of absolute elevation); further on it gradually slopes, becomes swampy, and only near the estuary of the brook becomes a dry terrace crossed by a small dry valley the lower section of which contains a brook. Emptying into the river in two branches, the brook flows around an islet beyond which it turns at a right angle and heads directly to the south. At the mouth of the Tente brook, there is a small outcrop on its left bank with the following profile:

0 to 53 cm - Coarse alluvium consisting of gravel, cobbles and small boulders cemented from the top by turf.

53 to 75 cm - Layers of gray sandy clay with single bands of purer gray sand.

75 to 106 cm - Layer of pure, plastic gray clay with single small bands of sand at a depth of 80 to 82 cm.

106 to 156 cm - Massive gray sandy gravel disappearing under water.

Somewhat upstream along the brook (180 m) we cleared its left bank, which is on the edge of a swampy terrace at an absolute elevation of 83 m.

0 to 70 cm - Peat.

70 to 90 cm - Compact silt-covered sand.

90 to 350 cm - Compact gray sand with gravel and cobbles.

The river bed narrows to 25 m at Yuryev rapids, but immediately beyond, it widens to 75 to 100 m, and the river is turbulent throughout. (Figure 19: Photo. Yuryev rapids.)

In the investigated district the river's left bank differs considerably from the right. The elevated sections, which in the region of the rapids slope continuously to the water level, further south they stop short of the bank; the entire area between the bank and a steep elevations 200 to 250 m in width represents a complex system of residual terrace dissected by deep dry valleys and ox-bow lakes.

As previously mentioned, the bedrock outcrops on the left bank near Yuryev rapids form the steep upper edge of a deep dry valley running along the present course of the river. This valley is separated from the river by a residual terrace about 6 m high, which is in the form of a narrow ridge and consists of large, highly eroded boulders (1.5 to 2 m in diameter). The continuation of this terrace is clearly noticeable on the other bank of the valley where it attains a width of 20 m. Slightly further south, this ridge abruptly plunges toward the transverse valley which represents the river's recent bed. It is quite possible that even at the present time this bed is used by the water in the spring when there are floating ice obstructions. This old bed, combined with the valley mentioned above extends along the river and opens into the present valley at a distance of about 1 km from Yuryev rapids (at corner 48).

The nature of the material in the terrace changes as we move south. Accumulations of large boulders grade into accumulations of smaller boulders, and further on, into large pebbles. This terrace is not horizontal; it slopes toward the south maintaining, however, its relative elevation above the level of the river. (Figure 20: Photo. Terrace on left bank of the Niva below Yuryev rapids).

Downstream, beyond corner 49, there begins a new, completely horizontal terrace 75 to 100 m wide with an absolute elevation of 95 m. This terrace is composed of finer material; boulders are rare on its surface. Clearing of a precipice near the river yielded the following profile:

Level 1 0 to 2.60 m - Coarse pebbles solidly cemented by ferric oxides, slightly stratified. Highly eroded gravel 10 cm in diameter near the surface, becoming finer at lower levels and turning into fine gravel.

Level 1 [sic.] 2.60 to 3.40 m - Medium-grained, stratified sand, slightly cemented and moist; layers are almost horizontal with a slight dip toward the bank.

Level 3 3.40 to 4.75 m - Coarse gravel of varying textures, brown-grayish, saturated with water.

Level 4 4.75 to 5.10 m - Coarse boulder gravel with single lenses and clay. Water appears everywhere, Level 4 is separated from the underlying by a sharply defined horizontal surface.

Level 5 5.10 to 7.75 m - Gray, stratified, compact, fine-grained, silty sand with boulders.

Water emerges along the entire profile. The elevation of the outcrop is 8.90 m.

In the southern part, a dry valley cuts deeply into the terrace which is of the same elevation on the other bank also. A small brook coming from the eastern elevations flows into the central part of the valley where it makes a turn at a right angle and flows in the valley along the Niva River. Immediately beyond the point where the brook enters the valley, a steep spur of the terrace slopes down to the next flat terrace at an absolute elevation of 90 m, which also slopes abruptly to the first "Plësozero terrace 81 to 82 m high. As we move south, the terrace material becomes finer, the boulders disappear almost completely except in the river bed, and fine, slightly silty sand appears in outcrops.

Thus, our observations in the section described above lead us to the following general conclusions.

The sloping terraces found in the upper part of the valley (beginning from the Razboynik and Yuryev rapids), containing first very large, rounded boulders, which gradually become smaller, are evidence that they were formed by a rapidly flowing river. Near corner 49, this river flowed into a standing body of water at an absolute elevation of 95 to 97 m. As the water level became lower, the flat terraces on the banks around this body of water were left on the valley sides and they are very well preserved in the lower parts of the valley. The stages of the lowering of the lake level correspond to the terraces at marks 91 m, 86 m, and 81 m. At the present time there is a wide terrace at the inlet of the Niva into Lake Plësozero at mark 77 m. The existence of a ponded body of water here is corroborated by the structure of these terraces which consist of horizontally-bedded, fine, silty sand. The change in the fraction in the outcrop described above indicates that a temporary lowering of the water level took place which was followed by another rise in the water level.

Section 6. Plësozero Depression

Lake Plësozero represents a calm section of the Niva ("plëso") stretching southwest for 4.5 km with a width of 125 to 250 m and a

maximum depth of 6 m. In contrast with the preceding section, the valley abruptly narrows in this area to a width of 350 to 400 m. The lake is situated in a deep, extremely picturesque valley. To the east, Plës-tundra rises steeply to an elevation of 440 m, while to the west, beyond the railroad line, the "varaki" hills slope down the lake (Figure 21: Photo. Inlet of the Niva River into Lake Plësozero from the right bank; in background is Plës tundra).

The shores of the lake are quite monotonous and are either sand or clay banks replaced farther inland by well-defined sandy terraces.

As for the structure and character of the right shore, near the northern end of the lake, beyond a sand-clay bank which dries out during the low-water period showing isolated boulders on its surface, the shore appears as flat, wet terraces which rise toward the railroad line. On the first, well-defined terrace, at an elevation of 81to 82 m, in the center of a sphagnum swamp with occasional dwarf pine trees, we drilled a test hole to a depth of 12 m into fine, gray, silty sand with small bands of gravel.

The next hole (diameter 2.5 m) was dug somewhat further south on a swampy terrace 91 m high, covered with a swamp full of hillocks, sphagnum, cloudberries and a sparse forest of dwarf pine trees. The hole had the following profile:

0 to 86 cm - Slightly decayed peat.

87 to 240 cm - Brownish-gray fine sand with gravel and boulders.

240 to 300 cm - Light gray, slightly clayey fine sand with boulders.

300 to 330 cm - Lighter, medium-grained sand with large quantities of gravel and boulders.

330 to 380 cm - Greenish-gray, fine-grained silty sand with boulders.

380 to 600 cm - The same sand of a somewhat coarser texture.

600 to 712 cm - Fine, greenish-gray sandy loam without boulders.

Higher up on the slope on the railroad line near the 1186-1187 km post, there is an old ballast pit with a newly-cut section. The pit is cut into a small hill of about 125 m absolute elevation. The slope facing the river is terraced, some terraces being well-defined along the entire slope, while others are not clearly defined and appear to be fragmentary. By eye, the well-defined terraces seem to be situated at 110 m, 115 m, and 118 m, while at 123 m there are only traces of a terrace. Clearing away the face of the pit to a depth of 6 m yielded the following profile:

0 to 10 cm - Soil horizons.

10 to 40 cm - Fine, uniform-grained sand with occasional small boulders and larger boulders (up to 30 cm in diameter).

40 to 192 cm - Yellow-gray, fine, homogeneous sand, without boulders, horizontally stratified, interbedded with finer, dark-gray bands of silty sand from 0.5 to 3 cm thick. Bands were noted at the following depths (in cm): 65, 72, 75, 90, 110, 117, 126, 132, 143, 147, 152, 162, 167, 183, and 192. These dark-gray bands with a considerably higher moisture content are occasionally accompanied by rusty-brown bands (ferric oxides). Occasionally rusty spots show plant root systems.

192 to 235 cm - Quantity and thickness of dark bands increase considerably.

235 to 241 cm - Clayey bands of gray, slightly greenish, clay.

241 to 261 cm - Gray, fine-grained, homogeneous sand.

261 to 263 cm - Clayey band.

263 to 285 cm - Gray, uniform-grained sand.

285 to 290 cm - Sandy loam band.

290 to 310 cm - Gray medium-grained sand.

310 to 315 cm - Clay layer.

315 to 350 cm - Gray medium-grained sand.

350 to 360 cm - Greenish argillaceous bands amidst gray sand.

360 to 370 cm - Gray medium-grained sand.

370 to 376 cm - Clay layer.

376 to 470 cm - Gray sand with some clayey bands at 415 and 425 cm depth.

470 to 575 cm - The same sand, saturated with water -- quicksand.

The above stratification character is maintained throughout the entire extent of the pit.

Water trickles out at the foot of the entire outcrop, and in the small puddles a layer of pure clay is deposited.

Near the base of the pit we drilled a hole in order to investigate the structure of the deeper-seated layers. The mark at the opening of the hole is 99 m absolute elevation.

0 to 15 cm - Gray, fine, uniform-grained

and from the terrace.

15 to 106 cm - Grayish-yellow, uniform-rained , fine sand.

106 to 187 cm - Greenish-gray fine-grained, ayey sand with pebbles.

187 to 277 cm - Coarse-grained, gray sand ith pebbles.

277 to 336 cm - Fine-grained, gray, clayey and.

As previously mentioned, the pit is cut into e foot of the hill which rises to the west. etween the railroad line and the Kandalaksha-ola highway the slope is covered with polished locks of country rock. Occasionally we encountered well-polished outcrops of medium-rained biotitic granite-gneiss, having the hape of small spurs, with a dip of 173° SE t an angle of 40°; 80 m west we discovered an utcrop of coarsely-banded, micaceous, hornlende gneiss with a dip of 120° SE at an angle f 15°. On the top of the hill (point 16) red icaceous granite-gneiss outcrops with a dip f 318° NW at an angle of 10°. At a distance f a few meters there is an outcrop of fine-rained, micaceous hornblende gneiss having latitudinal strike and a dip of 18°. Further own there is a plagioclase zone of gneiss hich is very poor in nonferrous minerals.

On the eastern slope of the hill (point 17) e encountered for the first time, very extensively developed layers of boulder accumuations. This hill, 210 m in elevation, tretches in a southeastern direction; from s foot to half-way up the northern slope it is overed with a series (4) of rows of boulder eds. The three lower ones are small in ize and 2 or 3 m high; the fourth attains a eight of 10 m and has a very steep slope acing north, and a short 2-meter slope from e opposite side, i. e., that facing the top. he layers are composed of large, partly roded, partly angular boulders, are covered ith vegetation and a thin layer of peat soils, o that the peat does not conceal their bouldery tructure.

The northern slope of the ridge is very steep, hile all the others slope very gently. Irregular boulder accumulations are also encountered n the summit of the hill which, in addition to oulders, is covered with sand of medium oarseness. On its southeastern end we encountered an eroded moraine of the same type s that described earlier. Under the moraine, hloritized gneiss outcrops with a 0° [sic.] dip t an angle of 20°. From here, two wide enches descend in a southeasterly direction, e., parallel to the hill's axis. At point No. 19 here is another outcrop of red, fine-grained, icaceous-hornblende gneiss with a dip of 73° NE at an angle of 12°. The edge of the last bench, i. e., the northeastern slope of the hill, is covered with numerous layers extending toward the southeast, up to 3 m high, with steep slopes, and composed of sand, gravel and pebbles. However, this applies only to the surface of the beds, because we had no opportunity to dig test holes. West of the hill there are swamps.

Further to the south, hills separated by deep stream valleys become higher and form an uninterrupted complex of high, forest-covered "varaki".

At the 1, 182 km post on the railroad, an elevation of approximately 200 m slopes from the west to the valley of Lake Pinozero. The top of this elevation is almost completely bare of eroded material and consists of well-eroded outcrops of micaceous gneiss (gray and pink, leucocratic) (sample 158), with a strike NE at 30° and a dip to the SE at an angle of 20°.

The above-described hill is the western member of a range of hills extending far to the northwest. Near the Kandalaksha postal road the gneiss outcrops are covered with boulder alluvium. No outcrops were found on the slope of this hill, which is entirely covered with vegetation. At the bottom part of the slope near the railroad, benches of the landslide type make their appearance. The hill is cut by the canyon-shaped valleys of two small streams which dry out in the summer. Along the railroad line there is a pit approximately 250 m long and with a maximum depth of 12 m. To the south and north of the hill the edges of the pit become lower.

In the central part of the pit the following structure was established by means of excavations (fig. 22).

A clay stratum of equal thickness and at the same height has been observed throughout the entire outcrop, and only in some places has a landslide on the slope been noticed.

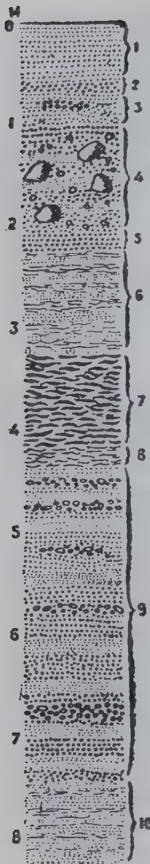
Excavations of the shores of Lake Plësozero from its northern tip to km 1,187 on the railroad everywhere show the same picture of deposition clay sections from the slope on the shores, and the formation of quicksand from fine sand mixed with clay. Here and there the deposited clay occurs in layers of more than 1 m.

Excavation III in the central part of Lake Pinozero on the right shore 8 m bank from water line and 30 to 35 cm above it:

0 to 30 cm - Sticky, light gray, clayey layer.

30 to 50 cm - More compact and darker dry clayey layer.

50 to 120 cm - Layer of pure clay (not explored to its bottom).



1 0 to 57 cm - Medium-grained, friable sand, soil layer.

2 57 to 63 cm - Coarse-grained, well-washed yellow sand.

3 63 to 93 cm - Medium-grained yellow sand with intercalations and lenses of gravel and pebbles.

4 93 to 205 cm - Coarse, gray sand with gravel, pebbles and isolated boulders. Friable and moist. Contains occasionally separate lenses and bands of fine, ochre-colored, homogeneous sand.

5 205 to 219 cm - Homogeneous, yellow, well-washed, medium-grained sand.

6 219 to 323 cm - Brownish-gray, moist, horizontally-bedded clay breaking up into small acute-angled lumps and columns when dry. A few thin layers of gray, homogeneous sand without clay fractions occur. Clay contain plant residues.

7 323 to 410 cm - Bluish-gray, plastic loam, slightly bedded, with single thin, sandy, lighter-colored horizontal bands. Of the varved clay type.

8 410 to 436 cm - Yellow-gray clay with brown bands.

9 436 to 742 cm - Yellow-gray, coarse sand with streaks and lenses of gravel and pebbles.

10 742 to 780 cm - Grayish-blue clay sand with pebbles and isolated small boulders concealed by talus.

FIGURE 22. Diagram of pit section at 1,182 km post on the Murmansk railroad

Here and there along the shores of Lake Plesozero there are well-defined terraces. West of the southern end of the lake there is a chain of elevations which represent the watershed between the brooks flowing into the Niva and the source of one of the tributaries of the Savina River. The surface of the hills is covered with sand and angular, eroded blocks of rock and there are no country rock outcrops. A small excavation (point 39) to a depth of 50 cm, exposed gravel with a small admixture of pebbles.

The left shore of the lake has the same character, viz., series of wide terraces from which the Plés-tundra rises in a steep slope.

A flat sandy and clayey bank, flooded during the high-water period, extends along the lake proper. A second terrace, about 4 m high, descends steeply to this bank. The structure of the terrace could be judged from an excavation made at the northern end of the lake:

0 to 160 cm - Yellowish-gray, fine-grained layers of sand with large quantities of gravel, here and there in bands and lenses up to 20 cm thick.

160 to 210 cm - Cross-bedded, coarser sand with gravel and pebbles, containing large quantities of mica scales.

210 to 310 cm - Yellowish-gray, fine, fine-bedded sand. Streaks of dark-gray, finer or silty sand 5 to 10 cm thick are encountered occasionally.

In front of the outcrop there is a bank of fine gravel piled up into banks by waves.

Near the central part of the lake, the Plës-tundra slopes directly down to its shore. The lower parts of the slope are slightly terraced, while the upper part is more even and steeper.

South of the Plës-tundra the same 4-meter terrace, attaining a width of 100 to 150 m, again extends along the shore.

The surface of the terrace is perfectly level and is covered with pine forests. Boulders are rare.

In the southern part, towards the end of the lake, the nature of the shore changes abruptly. Enormous quantities of large boulders cover

the shore strip and the slopes of adjoining heights. The southern edge of the lake seems to lean against a high moraine ridge across which the river has dug a narrow (about 30 m wide) valley.

Thus, in the district of Lake Plësozero we see a narrowing of the river valley, perfectly-defined accumulation terraces at 1, 4, 7, 12, and 22 m, and a series of higher, but less well-defined, terraces.

The structure of the valley slopes and the features of the outlet are evidence that once the level of the lake was considerably higher (no less than 110 m absolute elevation) and that it dropped in stages, as a result of which the present terraces were formed.

Section 7. Plësozero Moraine Ridge

As at the outlet of the Niva from Lake Pinozero, the outlet from Lake Plësozero is blocked by a high moraine ridge across which the river has to dig its way. The absolute elevation of this ridge is 115 to 120 m. At the point where the river breaks through the moraine ridge, its left bank is quite steep, covered with large boulders and has no terraces, while the right bank slopes more gently and contains a number of terraces.

Both slopes of the valley are covered with sod. At the point where it breaks through the moraine, the river forms rapids in a rocky bed with boulders (Figure 23: Photo. Outlet of the Niva from Lake Plësozero. View from the right bank). Somewhat further downstream near a sharp bend to the west there is an excellent outcrop 14 m high. Clearance of this outcrop yielded the following picture of the structure of the moraine ridge (fig. 24):

0 to 210 cm - Unstratified, fine, morainic clay soil, light gray, with large boulders, rubble and gravel. A sharp contact separates the moraines from underlying deposits.

210 to 280 cm - Light-yellow, fine, horizontally-bedded sand with individual gravel bands and dark bands of fine silty sand.

280 to 305 cm - Cross-bedded, coarse sand with gravel.

305 to 365 cm - Fine, homogeneous, yellowish-gray sand with silt bands of darker shade.

Below, there is a large talus where we could make only a few excavations which showed, however, that the material is homogeneous to the very bottom of the outcrop. Near the water level the same fine bedded sand crops out similar to the sand from the outcrop at 1,182 km. Plant or animal remains were not found in this sand.

Thus, we have here a moraine which covers stratified deposits. The lower limit of the moraine lies at an absolute elevation of 84 m.

Section 8. Lower Course of the Niva River

Downstream of the moraine, the direction of the river and the character of the valley change abruptly. From Lake Pinozero to the moraine, the course of the valley was south-southwest, whereas downstream it turns to south-southeast. The valley becomes considerably wider and the elevations recede to the sides. Starting from the river bed, a fairly flat terrace runs along the left bank; it is covered with large boulders and slopes gently in the direction of the river's course and reaches water level at the point where the river widens, at 23.5 km from its outlet from the lake. Down to Kandalaksha Gulf the valley on the whole, retains the same character. Its terraced sides slope gently towards the river.

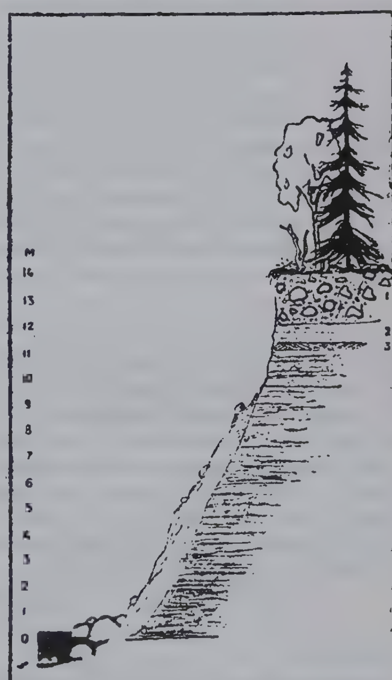


FIGURE 24. Diagram of the section of the Niva's left bank downstream from Plësozero

Only 1 km above Kandalaksha station there is a high hill near and east of the river. This hill is composed of garnet amphibolite with a few granite outcrops (sample 489) in a rocky cliff. Except for the area near the river mouth where crystalline rocks crop out, no other outcrops were encountered on the left bank.

The side of the valley is terraced, and these terraces can in places be followed for considerable distances, while at others they appear as fragments of terraces. The best-defined

ones are found at the following absolute elevations: 85; 70; 55; 47; 40; 34; 26; 18; 10; 5 m. All the terraces are flat and do not even slope with the gradient of the river. There are, however, three river terraces, visible at some places, at 5, 10 and 17 m relative elevations, which do slope parallel with the river gradient.

Near Kandalaksha proper on the left bank at an elevation of 10 and 26 m we encountered well-preserved gravel formations in the form of banks, ridges and flat areas covered with large well-eroded and washed gravel. Here and there, low eroded cliffs were noted, too. All this is evidence that not long ago the water level was at the elevations mentioned above. (Figure 25: Photo. Mouth of the Niva near Kandalaksha. Marine terraces are visible in the left bank).

The right bank of the Niva shows considerably smoother topography. Instead of high ridges and hills, there are low, gently sloping ridges and hills of small relative elevation.

Near the 1,891 km, 200 m from the railroad line at an elevation of 80 to 90 m, there is an outcrop of fine-grained biotite gneiss occurring in the form of a low bench, facing toward the northeast and extending for about 5 m. The rock breaks into angular fragments whose shapes are close to that of a pyramid or a trihedral prism, and is impregnated with red feldspar veins. The gneiss strikes 115° SE at an angle of 17°.

Further south there is an eroded moraine, almost 50 m high, which slopes directly to the Niva valley; the moraine trends northeasterly. The entire area around point 43 is a hilly plain whose apparent dimensions are one square kilometer. Small hills 15 to 20 m high are distributed at random here, although their general trend seems to be from southwest to northeast. Blocks and debris mainly consist of feldspar gneiss; rocks of other than local origin have not been found here. The basic material constituting the hills is gravel and fine, roughly eroded pebbles. Of exactly the same structure are the layers near the railroad line where they crop out in borrow pits. Here and there outcrops of fine-grained biotite gneiss are encountered.

The slightly undulating plain slopes gently towards Kandalaksha. The Niva has cut its bed into this plain. At the highest point of this area we made a 1 m excavation. At the top we found medium-grained, stratified sand without any larger admixtures. Its thickness is 60 cm. Underneath, there is gravel with pebbles and slightly eroded rock fragments; as a whole, the material is very slightly worked and has no admixtures or clay. The thickness is 10 cm. Underneath there is a compact layer of greenish-gray sand with admixtures of gravel, fine angular pebbles and fragments of country rocks. The contacts between layers are sharply defined.

Near Kandalaksha the area looks like a plain sloping toward the sea, its surface profusely covered with boulders.

In order to explore the relief and structure of this area, M. K. Karpun made an exploratory survey from Kandalaksha station north-northwest to the Savina River. The entire area between the coast and the first high hills - "varaki" - is a low-lying plain slowly rising to the north toward the interior of the peninsula. The lowest parts of this plain are covered with swamps, with many hillocks which merge to the north with the flat hills. Considerable quantities of boulders are found in the swamps. Further to the northwest, the area rises and becomes hilly. These hills are spread out in oval or elongated low hills consisting of coarse boulder sand and covered with medium-size boulders. These hills represent the base of high "varaki" which border the area to the north. An excavation dug in one of these hills (point 208) on the spot of a former barracks shows that this hill is composed of well eroded boulder-sand material. The abundance of boulders on the surface is evidence that the finer soil is being washed away from the surface of the hill. On the north and northeast, this area is enclosed by a fairly high ridge (points 209 and 210), which slopes sharply to the south. Its slopes are covered mostly by barren boulder fields which occasionally extend to the top of the ridge. The central part of ridge somewhat resembles a col between the higher edges; its relief and structure sharply differ from those of the outer parts. The col is filled with pure washed sand with almost no boulders and has a gently sloping relief consisting of a series (about five) of sandy, wave-cut banks which parallel the relief pattern and consist of well-eroded material. Their height is about 30 cm, their width 50 to 60 cm, and their length 5 to 10 m. The above ridge is followed by a higher "varaka" (point 213). Its southern and, to some extent, western slopes are an uninterrupted talus consisting of larger blocks on the top and smaller, acute-angled fragments at the foot. The flat surface of the "varaka" is covered with vegetation; blocks and boulders covered with lichens protrude here and there.

In descending from the "varaka" in a southwesterly direction we encountered many hills with much boulder material. Further in the same direction the quantity of accumulated boulders decreases; in some places they protrude as crests on tops of the hills, and in others they appear as talus on their slopes. The topography of the area becomes softer and smoother as small sandy hills begin to predominate. The latter characterize the entire low-lying region. The closer we approach

the Savina River, the more frequently we encounter small saucer-shaped depressions, flat divides and basins (occasionally funnel-shaped). There is sand everywhere; the depressions are filled with small swamps. The area slopes toward the Savina River from a steep slope 10 to 12 m high, where boulder talus emerges. The Savina River flows between the hills and forms a chain of small ponds and "plĕsy"; the river almost looks like an overflow between these ponds. The depressions themselves are quite different, containing lakes. The latter are overgrown with vegetation from their banks; commonly they are surrounded by cloudberry-covered swamps where the water is either stagnant or flows very sluggishly. Swamps filling the depressions between hills and opening towards the river are frequently encountered along the Savina River. At times they extend in benches along the slope.

The typical vegetation of these swamps consists of blueberries, cloudberries, green mosses, sphagnum, sedges and sparse fir trees. The drier ones have no sphagnum, but Ledum instead.

GENERAL CONCLUSIONS

Structure of the Crystalline Basement

Basically, the entire investigated region is composed of crystalline schists, prevailingly biotite and hornblende gneiss with individual bands and lenses of amphibolitic gneiss and granite-gneiss. Elevations of more considerable height consist of garnet hornblende schist which is particularly well developed in the area of the Kandalaksha Mountains. Occasionally the schist is intruded by gabbro-diabasic rocks and numerous thin quartz and pegmatite veins which at times run parallel to its strike, and at others cross it. In the area of Razboynik rapids we found a fairly wide vein (about 6 m) of melilitic porphyry intersecting the strike of the gneiss. The crystalline schists occur in numerous folds which strike prevailingly east-southeast, and which in some places are large and flat, or small and gently dipping. This major folding is complicated by a minor set, which reaches the stage of plication and somewhat upsets the overall picture of stratification. In some places the schist is contorted to such a point that over even a small distance strikes of nearly every direction can be measured.

In addition to the above foldings, an important role is played in this region by faults. There is no direct evidence of such faults, although the nature of the topography of the crystallines, the strict regularity of the main trends of the topography and the direction of the depressions, lakes and river valleys would tend to support their existence.

Ancient Relief

Ancient folds in the gneiss have practically no effect on the present relief. The synclines, or their limbs, frequently produce elevations in the relief, while the anticlines are represented by depressions. The present relief of the base is without doubt of a more recent origin and depends on recent tectonic activity and subsequent erosion in directions influenced by such activity. Individual sections of the valley, as well as the trend of the main elevations adjoining the valley follow the two main tectonic directions, viz., southeast and southwest. The thickness of the alluvium concealing the outcrops of the country rock is quite negligible, except for a few districts which will be discussed later. As a rule, bedrock crops out more frequently on the western and northern slopes of the high hills and mountains adjoining the valley, less frequently on the southern. In flat areas outcrops of country rock occur frequently in the depression adjoining Pinozero on the west. In the Imandra depression and the southern part of the Niva valley, the outcrops of country rock are hidden under alluvium layers, although here also outcrops on lower elevations evidence their occurrence close to the surface. The maximum depth is attained by the country rock near Razboynik rapids, where a test hole on the right bank 50 m from the rocky left bank, was put down to a depth of 67 m (36 m absolute elevation) without hitting bedrock. At some 0.75 km west of this point, the bedrock is covered by a relatively thin layer alluvium (about 5 m) and occurs at an elevation of 120 m above sea level; further west, at a distance of 0.5 km, bedrock crops out at an elevation of 150 m. The narrow and deep, alluvium-filled crevice described above has a southwest strike; it determines the direction of the Niva and reaches Lake Pinozero in the north. Near the shore of Lake Pinozero it is filled with lake alluvium and has no bearing on the topography of the area. However, the existence of outcrops of country rocks on the right bank of the Niva at water level and on the left bank at a distance of 0.5 km, and the absence of outcrops in the central part where the test hole went down to 30 m in the alluvium, is evidence that the crevice runs further to the north.

The rectilinear pattern of the Niva valley over its entire distance is apparently due to the fact that it follows this crevice.

Quaternary Deposits

The alluvium covering the crystalline basement is not a continuous blanket deposit, for there are outcrops of country rock almost everywhere; however, the thickness of the alluvium is not uniform, occasionally attaining no less than 80 m (at Razboynik rapids).

According to its character and origin, the alluvium can be divided into the following groups: 1) unstratified deposits (moraine) and 2) stratified deposits, the latter being

classified into a) fluvio-glacial, b) lacustrine, c) fluvial, and d) marine.

Unstratified Deposits (moraine)

Over the entire extent of the river, the moraine is quite monotonous both in its appearance and mechanical composition. It consists of unstratified gray sand with a slight green shade like dry cement; only under large boulders does it form something like a bed of purer yellow sand. The boulders which are scattered over the entire moraine are of a fairly uniform petrographic composition and consist prevailingly of local rocks; boulders transported from other regions are rare here. A characteristic feature is the absence of boulders consisting of nepheline syenite, and the presence of epidote granite boulders, like those on the Kandalaksha shore, even in the northern parts of the valley. The boulders are mostly angular and lightly eroded, although well-eroded ones are also found. Some of them have well preserved striae and scratches. Large quantities of poorly rounded rubble of varying sizes is scattered in the basic mass of clayey sand.

Unwashed moraine covers the greater part of the slopes of the higher elevations and forms three ridges which intersect the Niva valley at the rapids of Lake Pinozero, Razboynik, and Lake Plësozero. North of the Pinozero ridge the moraine is covered with alluvium beds up to an elevation of 138 m above sea level. Near the Pinozero outlet, below 120 m above sea level, the moraine is associated with outwash. South of the ridge at Razboynik rapids, at an elevation of 110 to 115 m above sea level the moraine is replaced by outwash deposits; at Plësozero rapids the lower edge of the moraine is at an elevation of 87 m above sea level. Beneath the alluvium bed, underlying the moraine in the area of Razboynik rapids, at a depth of 50 m from the pit (about 70 above sea level) we found a second layer of a more clayey reddish-brown moraine material which apparently belongs to an earlier period of glaciation.

Stratified Deposits

Fluvioglacial Deposits: We may consider the alluvium in the northern part of the Niva valley, characterized by an extremely irregular, yet sharply defined, cross-bedding of well-sorted but poorly-eroded material, and with lenses of poorly-sorted sand with boulders and gravel. They were apparently moraine material carried out by late-glacial waters and deposited in a shallow lake whose level was slightly higher (by 8 m) than that of Lake Imandra today.

Lacustrine Deposits: These deposits in the area of Lake Pinozero are represented by bedded clay, sand and gravel (cf. description of profiles), which form lacustrine terraces at 2.5 and 8 m above the actual level of the lake. In the area of Lake Plesozero, similar stratified deposits were found on the shores, in the profiles of terraces, as well as on the slopes of the valley at great heights with respect to the level of the lake today (35 m). The characteristic feature of the Plësozero deposits consists of the regular, horizontal stratification and uniform thickness of strata over long distances, which is evidence of calmer deposition conditions in the large reservoir. The same alluvia occur under the moraine ridge at Razboynik rapids. Despite careful research, no organic residues could be detected in this alluvium; analysis for diatoms also yielded no results; thus the problem of the origin of this sand remains unsolved. It is quite possible that these deposits are related to interglacial transgression.

Fluvial Deposits: These deposits have no particular significance in the northern part of the river valley; however, they acquire considerable importance in the district between Yuryev rapids and the northern tip of Lake Plësozero, as well as in the district south of Plësozero rapids, where they form the fluvial terraces described above.

Marine Deposits: Neither we nor earlier explorers found any typical marine deposits with remains of fauna in the Niva valley; however, a number of morphological characteristics (coastal banks, wave-cut cliffs, etc.) are evidence that the sea level was once higher. Ramsay, discovered the highest evidence of wave action at 163 m, Ayllo at 145 m. On the slope of Volostnaya tundra I discovered well-defined coastal gravel banks at 110 m, above which there were bare rocks (Figure 26: Photo. Gravel terraces on the slope of Volostnaya tundra, 110 m elevation). Similar gravel banks were found in the Niva valley at 45, 25, and 11 m; occasionally, terraces at 70 and 75 to 77 m were well-defined. Near the outlet of Niva from Lake Plësozero, at 84 m above sea level, bedded sands are covered with unwashed moraine. At this elevation is the contact between washed and unwashed moraine on the right bank of the Niva. However, also above this contact we found terrace-shaped benches which are not clearly defined and are covered with a moraine blanket. The character of the material constituting the benches varies from clay at the bank, to sand in the first terraces, and to accumulations of large, well-eroded gravel in the upper parts. In the Niva valley proper there emerges poorly sorted sand with boulders and gravel.

The latest deposits are represented by peat bogs situated in all the depressions; in most cases they are fairly shallow (1 m deep). The largest peat bogs, both in area and depth, were found in the depression west of Lake Pinozero.

Evolution of Niva Valley

Like the majority of rivers on the Kola Peninsula and Karelia, the Niva consists of separate, completely independent, parts each of which has its own history of evolution, and which only recently have been combined into one single system.

The main trends of the Niva valley are associated with fairly youthful (apparently Tertiary) faults. These fissures were enlarged by preglacial erosion. Argillaceous moraine clays, preserved in the deeper parts of the fissure near Razboynik rapids are probably remnants of the first glaciation. Apparently, a second glaciation has, at a later period, almost completely destroyed not only the traces of the first glaciation, but also those of the interglacial marine transgression. The entire complex of post-Tertiary deposits appears to be the product of later periods of glacial activity, except for the above-mentioned argillaceous moraine clays tentatively referred by us to the first glaciation period. The main mass of the glacier moved in a southeast direction and cut across the strike of the Niva valley in directions evidenced by the system of the southeast faults. During the period of maximum glaciation the low elevations encountered by the glacier on its path were not obstacles, and it passed over them, eroding and leveling the slope of impact somewhat but leaving the opposite end steeper. As the glacier decreased in thickness, isolated summits were transformed into nunataks; at the same time, at the sides of the glacier, terrace-like accumulations of moraine material were formed which were preserved on the slopes of the elevations. The ice layer broke up into several tongues moving between these elevations. Within the area of the present Niva valley, two main glacier tongues were developed. The northern (and largest) moved from northwest to southeast along the Pinozero depression. It left traces in the form of bare, polished cliffs ("ram heads") both on the bottom of the bed and at the sides, as well as eskers deposited in the direction of the glacial movement. The southern ice tongue intersected the valley below Lake Plësozero and apparently moved southeast along the depression between Plësovaya and Zheleznaya tundra. It is possible that a part of this tongue was deviated to the south by the Zheleznaya tundra and joined the large Kandalaksha glacier. It is quite likely that at this time there were small local glaciers on some of the highest elevations which descended to join the main glaciers. The glaciers deposited huge lateral moraines which formed dams across the deep tectonic Niva valley. These lateral moraines of the northern glacier tongue were found well preserved north and south of Lake Pinozero, and those of the southern glacier tongue, south of Lake Plësozero. In spite of considerable erosion during postglacial inundation, the southern moraine ridge is fairly well-defined north of Kandalaksha station. After the ice melted, the tremendous volume of water, held back by moraine ridges, formed several large reservoirs at different elevations. Ramsay explained the evidence of shorelines on Syraya tundra and Kuzvarenche near Zasheyek station at an elevation of 197 m by the existence of such a reservoir in the place where Lake Imandra is situated today. Terraces of the same elevation were also noticed by our collaborators on the left bank of the Niva east of Pinozero rapids. Apparently, these terraces are related to the period when the Pinozero depression was covered by the glacier. After the glacier melted, both Lake Imandra and Pinozero apparently had a common outlet to Kandalaksha Gulf which was located considerably further west of the present one in the valleys of the Lupcha and Savina Rivers.

Once an outlet was established, the level of Lake Imandra dropped first to 138 m, and then to 130 m. At that time the level of Lake Pinozero was at 120 m, that of Lake Plësozero at 100 m, and that of the southern reservoir (fresh-water or sea inlet) at 75 m.

The uplift of the Kola peninsula, which apparently continues until today, began after the last glacial transgression. Our observations of the morphology of the shores of Lake Imandra from 1925 to 1927, corroborated by this year's (1930) observations prove beyond any doubt that separate parts of the Imandra basin rose irregularly. The greatest uplift is taking place in the northwest sections, which suggests a regression of the western parts of Lake Imandra and flooding of its eastern shores. This displacement of the level caused the lake level in the Zasheyek area to rise and interrupted its westward outlet. At 138 m absolute elevation Lake Imandra found an outlet into Lake Pinozero across the moraine ridge where the latter is in contact with the crystalline outcrops on the left bank. The wide and undeveloped valley of the Niva at its outlet has all the characteristics of youth; the tributaries flowing into it from directions almost contrary to its course bear evidence of the former south-north direction. Apparently, Lake Pinozero went through a similar transformation. The outlet to the west gradually became more difficult; as the uplift in the southeast sections lagged, the lake reached the top edge of the moraine ridge and flowed across it into Lake Plësozero. In digging its channel into the moraine along the contact with the rock outcrops, the Niva met resistance in the form of protruding rocks which inhibited the erosion of the ridge; this corresponds to the Pinozero terraces. When the Pinozero water broke through, the level of Lake Plësozero was at 95 m, which is evidenced by the junction of the oblique river terraces with the horizontal lacustrine terrace of a corresponding level.

Following a rise in the lake level and a more vigorous outwash of the ridge which obstructs Lake Plësozero from the south, its level dropped sharply by 4 m, which corresponds to a well-defined terrace at 91 m. Subsequently the level of Lake Plësozero began to drop in stages, which is evidenced by the terraces at 86, 83 and 80 m. The uplift of the Kandalaksha coast caused a recession of the sea and the formation in the lower part of the valley of another fresh-water reservoir which today is completely dry. Well-defined terraces at 45 m above sea level are evidence that for a long time a reservoir existed here separated from the sea by a crystalline ridge entering from the east (almost opposite Kandalaksha station) and a lateral moraine joining it from the west. Where the river flowed into this reservoir, a delta was formed, a remnant of which is a river island about 7 km from the Niva's mouth. The general characteristics of the wide part of the Niva valley differ considerably from the lower, canyon-like section. The lower section has a number of well-defined marine terraces at 26, 16 and 11 m above sea level.

The above outline of the formation of the Niva valley should be regarded as a first approximation, because the processes of irregular uplift and lowering of the peninsula, and the advancing and receding of the sea associated with it, are very complex and little known; moreover, poor knowledge of the surrounding regions makes it impossible to draw any general conclusions. Geological prospecting and drilling operations which are being carried out by Nivastroy will certainly yield new interesting data, which will cause us to revise and define more accurately the conclusions made on the basis of a reconnaissance survey.

Reference Section

RUSSIAN AND EAST EUROPEAN GEOLOGIC ACCESSIONS OF THE LIBRARY OF CONGRESS

This section is devoted to a listing of selected geologic items appearing in the two publications of the Library of Congress; Monthly Index of Russian Accessions, and East European Accessions Index. These lists are intended as a means of indicating to researchers in the earth sciences some of the material most recently available for screening, further review, and translation. For this reason the lists do not include material now, or soon to be, published in English. Emphasis is placed on Russian material; the extent to which items from East European sources are listed depends on the country and language involved.

A major function of the AGI translations program is the screening of foreign literature for material that should be made available to the English-speaking scientist. Researchers who need such material are urged to review these lists and send us their recommendations for consideration by the editors; the translation needs of all geologists will be served better thereby.

-- Managing Editor

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Tubielewicz, W. Coastal phenomena in the Hel Peninsula. p. 355.
Wawryk, W.; Piotrowicz, W.; Domanski, J. Argillaceous deposits from Bysewo and the Gulf of Danzig. p. 367.
Piatkowski, J. The original valley of the Reda River the dune separating the Leba Lake from the Baltic Sea, and the periglacial lake of Lebork. p. 375.
Piasecki, D. A geomorphological sketch of the Radunia River basin. p. 385.
Lomniewski, K. The mouth of the Vistula River. p. 391.
Orkisz, H. Henryk Arctowski (1871-1958); an obituary. p. 419.
Stopa, S. Tadeusz Antoni Bochenski (1901-1958); an obituary. p. 425.
Pazdro, Z. Bronislawa Kokoszynska (1897-1959); an obituary. p. 441.
Krach, W. Eugeniusz Panow (1890-1958); an obituary. p. 449.
Report from the 31st Scientific Conference of the Polish Geologic Society in Danzig, June 6-8, 1958. p. 433.
Czarniecki, S. Report from the activities of the Polish Geological Society in 1957/58. p. 459.

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13. SCIENCE

PRZEGLAD GEOFIZYCZNY. REVIEW OF GEOPHYSICS. (Polskie Towarzystwo Meteorologiczne i Hydrologiczne) Warszawa. [Journal issued by the Polish Society of Meteorology and Hydrology. Superseded Przeglad Meteorologiczny i Hydrologiczny, 1956. Quarterly]
Recurrent features: Review of literature; Bibliography.
Vol. 5, no. 2, 1960.
Paslawski, Z. Seepage of Warta River waters near Konin. p. 99.
Lewandowska-Skoczek, H. Seismicity in the region of the western Pacific Ocean during the International Geophysical Year as observed at the Kienan Station. p. 133.

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ARCHIWUM HYDROTECHNIKI. (Polska Akademia Nauk. Instytut Budownictwa Wodnego) Warszawa. [Journal on hydraulic engineering issued by the Institute of Hydraulic Construction, Polish Academy of Sciences; with English, French, and Russian summaries. Quarterly]
Recurrent feature: From Polish scientific laboratories.
Vol. 7, no. 2, 1960.
Paszyc-Sepkowska, E. Influence of the type of exchangeable ion on the physical and mechanical properties of bentonite. p. 143.
Gajczewski, J. Electrokinetic petrification of compact soils by ionization. p. 215.
Kuzniar, J. Influence of the mineral composition on the capillary ascent of minute fractions. p. 247.
Wieloch, R.; Gaca, W. A new method of underwater sealing of contrete. p. 261.

CEMENT, WAPNO, GIPS. (Wydawnictwo "Budownictwo i Architektura") Krakow. [Publication on adhesives in the building industry issued by Building and Architectural Publications. Includes a supplement: Przeglad Bibliograficzny Materialow Wiazacych, bibliography on adhesives. Monthly]
Recurrent features: Editor's answers; News from the foreign press.
Vol. 16, no. 9, Sept. 1960.
Nizinski, S.; Beben, A. Utilization of the cleavage of rocks for work with explosives. Pt. 1. p. 254.
Duchniewski, E. The Bogucianka-Zabiedzienie limestone deposit. p. 258.

GOSPODARKA WODNA. (Naczelna Organizacia Techniczna) Warszawa. [Publication on water-power resources and hydraulic engineering issued by the Central Technical Organization. Monthly]
Recurrent features: Bibliography; Book reviews.
Vol. 20, no. 7, July 1960.
Szechy, K. Contribution to the theory concerning lowering the ground water level. p. 296.
Boczek, M. Abridged measuring of the flow size by applying the harshness coefficient. p. 302.
Kornacki, Z. Causes for the bottom lowering of the Vistula River in Warsaw. p. 305.
Dadak, Z. Application of the rotary method to the rinsing machine for hydrogeological borings. p. 307.
Paslawski, Z. Escape of the water of the Warta River in the vicinity of the town of Konin. p. 331.

Katowice, Poland (City) Instytut Naftowy. PRACE. Katowice. [Papers on petroleum engineering issued by the Petroleum Institute; with English, French, and Russian summaries]
No. 64, 1960.
Zlotnicka, J. The correlation of crude-oil horizons of the oil field Tarnawa-Wielopole-Poraz on the basis of qualitative composition of petroleum ashes by spectrographic analysis. p. 3.

NAFTA. (Instytut Naftowy) Krakow. [Journal on petroleum engineering, processing, and management issued by the Petroleum Institute. Includes supplements: Przeglad Dokumentacyjny Nafty, documentation; Wiadomosci Naftowe, information bulletin; and Biuletyn Instytutu Naftowego, bulletin of the Institute. Monthly]
Recurrent feature: Information from the Institute.

Vol. 16, no. 8, Aug. 1960.
- Borowski, J. Activities of the petroleum industry in 1959. p. 203.
- Cimaszewski, L. Relation between the Tertiary tectonics of the Mogilno structure and the structure of the substratum. p. 206.
- Strzelbicki, J. The role of physicochemical properties of water in petroleum extraction. p. 208.

PRZEGLAD GEOLOGICZNY. (Wydawnictwa Geologiczne) Warszawa. [Publication on economic geology issued by Geologic Publications. Monthly]
Recurrent features: Organizational and legal problems: Brief notes: New publications; reviews and foreign periodicals: Standards and instructions.

Vol. 8, no. 8, Aug. 1960.
- Rozycki, S. Economic development of the Czestochowa region in relation to the history of geologic investigations. p. 401.
- Bialaczewski, A. Iron-ore deposits of the Czestochowa region. p. 406.
- Rozycki, S. For the name of the Polish Jurassic instead of the Krakow-Czestochowa Uplands. p. 408.
- Mossoczy, Z. The stratigraphy of the Lower Jurassic in the northern part of the Krakow-Czestochowa belt belt. p. 409.
- Deczkowski, Z. Characteristics of the Czestochowa-Wielun Dogger. p. 412.
- Rozycki, S. The stratigraphy and changes of facies in the highest Dogger and Malm of the Czestochowa Jurassic. p. 415.
- Znosko, J. Tectonics of the Czestochowa region. p. 418.
- Rozycki, S. The Quaternary of the Czestochowa Jurassic and of the adjacent area. p. 424.
- Bazynski, J. The geologic and technical characteristics of the Karst in the vicinity of Czestochowa. p. 430.
- Sedlak, W. Iron ores in the Cambrian of the Gory Swietokrzyskie. p. 433.
- Wojnar, K. The technical progress of coring in difficult geologic conditions. p. 438.
- Tkaczenko, A; Pietrus, W. Main trends in the development of the technique of geologic works for the years 1960-1965. p. 440.

PRZEGLAD GORNICZY. (Stowarzyszenie Naukowo-Techniczne Inzynierow i Technikow Gornictwa) Katowice. [Issued by the Scientific-Technical Association of Mining Engineers and Technicians. Includes supplements: Biuletyn Glownego Instytutu Gornictwa, bulletin of the Central Institute of Mining; Biuletyn Instytutu Mechanizacji Gornictwa, bulletin of the Institute of Mechanization in Mining; and Przeglad Dokumentacyjny Gornictwa, documentation. Monthly]
Recurrent features: Current news; Foreign review; Polish coal standards.

Vol. 16, no. 7/8, July/Aug. 1960.
- Lewowicki, S. The occurrence of coal among formations of the northern border of Gory Swietokrzyskie. p. 354.
- Poborski, C. The origin of methane in Carboniferous formations of the southern part of the Rybnik coal area. p. 360.

RUDY I METALE NIEZELAZNE. (Wydawnictwo Gorniczo-Hutnicze) Katowice. [Journal on the mining and processing of ores and the metallurgy of nonferrous metals issued by Minine-Metallurgic Publications; with English, German, and Russian summaries. Quarterly]

Vol. 5, no. 8, Aug. 1960.
- Konkolski, T. Drainage of a flooded mining field. p. 318.
- Cibis, J.; Cibis, J. Remarks on vitriolic loams. p. 331.
- Pers, S. Sources for covering poland's copper demand. p. 342.

WIADOMOSCI NAFTOWE. (Stowarzyszenie Naukowo-Techniczne Inzynierow i Technikow Przemyslu Naftowego i Zwiazku Zawodowego Gornikow Naftowcow) Krosno. [Publication on petroleum engineering and the petroleum industry for technical personnel issued by the Scientific-Technical Association of Engineers and Technicians of the Petroleum Industry and the Union of Petroleum Engineers. Monthly]

Vol. 6, no. 7/8, July/Aug. 1960.
- Glowacki, E. The geologic structure and the oil and gas of western Ukraine. p. 145.
- Jaworska, B. The use of radioactive isotopes in the exploitation of oil and gas. p. 151.

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12. GEOGRAPHY & GEOLOGY

BARBU, VIRGINIA. Contributii la cunoasterea genului Hipparion. [Bucuresti] Editura Academiei Republicii Populare Romine, 1959. 83 p. (Biblioteca de geologie si paleontologie, 5) [Contributions to the knowledge of the genus Hipparion. Russian summary. illus., map, bibl., footnotes, tables]

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ANALELE ROMINO-SOVIETICE. SERIA BIOLOGIE. (Academia Republicii Populare Romine. Institutul de Studii Romino-Sovietic) Bucuresti. [Journal on biology issued by the Institute of Rumanian-Soviet Studies, Rumanian Academy. Quarterly]
Recurrent features: Book reviews; Notes on Soviet scientific life.

Vol. 14, no. 2, Apr./June 1960.
- Ivanova, E. Means of developing paleoecology in Soviet Russia. Tr. from the Russian. p. 148.

16. TECHNOLOGY

PERIODICALS

Academia Republicii Populare Romine. Centrul de Cercetari Metalurgice. STUDII SI CERCETARI DE METALURGIE. Bucuresti. [Journal issued by the Center of Metallurgic Research, Rumanian Academy; with French and Russian summaries. Superseded in part Studii si cercetari de mecanica si metalurgie, 1956. See also Academia Republicii Populare Romine. Institutul de Mecanica Aplicata. Studii si cercetari de mecanica aplicata]
Recurrent feature: Book reviews.

Vol. 5, no. 2, 1960.
- **Mantea, S.; Petrescu, N. A study on the extraction of magnesium from dolomite by means of silicothermal reduction. p. 187.**
- **Moscovici, A.; Frumosu, G. Contributions to the recovery of titanium and iron from ilmenite concentrates originating from alluvion. p. 219.**

HIDROTEHNICA. (Asociatia Stiintifica a Inginerilor si Tehnicienilor din Romina) Bucuresti. [Journal on hydraulic engineering issued by the Scientific Association of Engineers and Technicians of Rumania; with English, French, German, and Russian summaries. Resumed publication of the same title, which was suspended Mar. 1954-Dec. 1955 (?). Monthly]
Recurrent feature: Documentation.

Vol. 5, no. 6, June 1960.
- **Lehr, H.; Stanculescu, I.; Stanescu, E. Some considerations related to the application of the calculation of limiting states of foundations. p. 195.**

Vol. 5, no. 7, July 1960.
- **Pietraru, V.; Zaharescu, E. Modeling the impermanent infiltrations; the Darcy-Poiseuille analogy method. p. 215.**
- **Maruta, A. On the approximate predetermination of the river bed modifications in the vicinity of the intakes with sills. p. 220.**
- **Abramescu, T.; Stoica, R. Some observations on the behavior of an experimental dike in Lake Razelm, region of Constanta. p. 224.**
- **Negulescu, M. Some considerations on the dimensioning of the captations of underground water. p. 230.**

REVISTA MINELOR. (Ministerul Minelor, Ministerul Industriei Petrolului si Chimiei, Directia Exploatarilor Miniere si Asociatia Stiintifica a Inginerilor si Tehnicienilor din Rominia) Bucuresti. [Publication on mining and related industries issued by the Ministry of Mines, the Ministry of the Petroleum and Chemical Industries, the Direction of Mine Operation, and the Scientific Association of Engineers and Technicians of Rumania; with Russian summaries. Monthly]
Recurrent features: Standardization; Book reviews; Correspondence with readers.

Vol. 11, no. 7, July 1960.
Romanescu, D. Utilization of magnetometric prospecting in geologic mapping. p. 311.

Hydraulic extraction in the exploitation of ores and coal. p. 329.

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HIDROLOSKI GODISNJAK; VODOSTAJI. Beograd. Izd. Savezna uprava hidrometeoroloske sluzbe. [Hydrologic yearbook on water levels issued by the Federal Administration of Hydrometeorologic Service. fold. col. map (in pocket), graphs, chiefly tables]
Year 1957. [Title varies: Hidroloski godisnjak. Annuaire hydrologique] 1959. 279 p.

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CESTE I MOSTOVI. (Drustvo za ceste Hrvatske) Zagreb. [Publication on projects, construction, and maintenance of roads and bridges issued by the Roads Society of Croatia. Monthly]
Recurrent feature: Information on personnel.

Vol. 8, no. 7, July 1960.
Bonacci, B. Rapid methods of terrain identification. Pt. 1. p. 165.

IZGRADNJA. (Drustvo gradevinskih inzenjera i tehnicara NR Srbije i Sekcija gradevinske operative NR Srbije) Beograd. [Issued by the Society of Construction Engineers and Technicians of Serbia and the Section of Construction Operative of Servia. Monthly]

Vol. 13, no. 1/2, Jan./Feb. 1959.
Catic, B. Construction of deposits of gravel and a concrete factory in Belgrade. p. 14.

NAFTA. (Institut za naftu) Zagreb. [Journal issued by the Naphtha Institute. Monthly]
Recurrent features: Bibliography; Book reviews; Petroleum dictionary.

Vol. 10, no. 9, Sept. 1959.
Vuckovic, J.; Filjak, R.; Aksin, V. Prospecting for petroleum in Yugoslavia: a report made at the Fifth World Petroleum Congress in New York City. p. 301.
Aksin, V. World Petroleum Congress. p. 310.
Kirigin, F. Impressions from the Fifth Petroleum Congress. p. 314.
Smirnov, M. Potentiality of the Soviet exportation of petroleum. p. 315.

RECENT TRANSLATIONS IN THE FIELD OF GEOLOGY

The second monthly listing of recent translations in the field of geology appears on these pages.

Sources for these translations are given below. For identification of source code initials and addresses, see the Reference Section of the January 1961 issue of IGR. The sources are:

Technical Translations, v. 4, nos. 11 and 12.

LLU Translations Bulletin, v. 2, no. 12.

AEC Translations List, Dec. 20, 1961, List no. 48.

Consultants Bureau Enterprises, Inc., Catalog 1960-1961 and undated pamphlets.

Not included in the listings are translations from the following seven Soviet journals in geology and related fields, which are published cover-to-cover.

Doklady, Akademii Nauk SSSR, ser. Geokhimiya, by CB

Doklady, AN SSSR, ser. Geologiya, by AGI

Geokhimiya, by the Geochemical Society.

Geologiya Neft (i Gaz), by Russian Review of Geology

Izvestiya, AN SSSR, ser. Gefizicheskaya, by AGU

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Translations are as follows:

Ananyan, A. A., 1959 Ice liberation mechanism in frozen ground during the electro-osmosis process: Moscow U. Vestnik, ser. matemat. mekh. astron. fiz. khim. (USSR) v. 14, no. 4, pp. 149-151. MDF, A-153.

Anonymous, 1957, Sources of iron ore for ferrous metallurgy of the U.S.S.R. Contents list only. Ed., I. P. Bardin: Izdatel'stvo AN SSSR Moscow. DSIR LLU, R. 12824.

__________, 1958, Problems of the theory of destruction of rocks by explosives: mono., Moscow, 223 pp. LC or SLA 60-23546

Astapov, S. V., Yemelyanov, V. A., and Shishkov, K. N., 1958, Experiments in the use of cobalt and iodine radioactive isotopes in land improvement investigations: Gidrotekhnia i melioratsiya (USSR) v. 10, no. 1, pp. 22-29. PL-480-PST no. 129. OTS 60-21151

Berger, Charles, 1959, Double calcium carbonate determination and the calcilog: Revue de l'Institut Francais du petrole et annales de Combustibles Liquids, v. 14, Jan., pp. 55-71. SLA 60-18102.

Bessonova, E. N., et al, no date, Investigation of of the mechanism of earthquakes: Geofiz, Inst. AN USSR, Tr. 40. CB

Bobelyuk, V. P., 1960, Influence of sand quantities and fluid types on the effectiveness of hydraulic fracturing: Neftyanoye Khoz. (USSR) v. 38, no. 2, pp. 41-49. ATS, 46M43R; ord. LC

Borodin, L. S., 1957, Geochemistry of the Khibina alkaline massif: Tr. Inst. mineral. geokhim. i kristallokhim. redkikh elementov no. 1, pp. 23-44. AEC-tr-4186; Ord. LC

Chao, Chiu-Chiang, 1960, Activities and prospects of International Geophysical Year. JPRS 5292; OTS 60-41164

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Fialko, Ye. I., 1960, On the velocity distribution of meteoroids. JPRS 5791; OTS 60-41554

Fridland, M. I., and Skoblo, A. I., 1960, Study of the process of particle elutriation from a fluidized bed: Izv. Vysshikh ucheb. zaved. neft i gaz (USSR) v. 3, no. 1, pp. 71-78. ATS, 30M43R

Gansser, A., 1960, Mud volcanoes and salt domes: Naturforsh. ges. Zurich, Vierteljahrsschrift (Switzerland) v. 105. ATS-71M43G

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Glazov, N. V., and Glazov, A. N., 1959, New instruments and methods of engineering geology. CB

Golenetsky, S. I., 1956, The processing of instrument observations of earthquakes by means of the epicentral method: AN Tadzh. SSR, Stalinbad, v. 54, pp. 41-56. SCL-T-306, ord. LC or SLA

Kalinin, S. K., 1958, Spectrographic determination of rare earths in minerals: in-ta yadernoi fiziki, AN KazSSR, v. 1, pp. 288-295. DSIR LLU, M. 1787

Kervella, I. F., 1958, Sedimentary uranium deposits in France and the French Union: Bull. info. sci. et tech. no. 18, p. 28; no. 17, pp. 11-28; no. 18, pp. 22-30; no. 19, pp. 16-31. AEC-tr-4187 or CEA-911 (French); ord. LC

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